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Scope and Value of Water Works Schools

By William T. Ingram, Raymond J. Faust, A. P. Black, H. N. Lendall, Edward R. Stapley and Charles R. Cox

A panel discussion presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J.

William T. Ingram

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THE members of this panel have been asked to discuss a number of specific topics relating to the scope and value of water works conferences and schools. Answers are sought to such vital questions as what types of programs are best suited to the training needs of water works personnel and which groups share, or ought to share, the responsibility of conducting these programs.

Information on training courses given in 1947 has been collected by the Engineering Section Project of the American Public Health Assn. A progress report based on returns from 41 states is summarized in Table 1.

Only 16 states reported water works training in 1947. A total of 24 training courses were offered at state, regional and local levels. At least 2,400 operators, superintendents, managers, consultants, public health agency employees and others received training in 1947. The cost of training to the enrollee varied from nothing for seven of the courses to $50 for one course. The training time varied from 1 day (8 hours) to 25 days (200 hours).

Sponsorship of Schools

The sponsorship of water works training programs has been variable in the past. This is indicated by the sponsorship of 1947 schools: state health department, 23; local health department, 0; public-official agency, such as New York's Conference of Mayors and Other Municipal Officers, 2; water works association, 19; university, 18; and local water works, 1. The general pattern is a combined sponsorship by the state health department, a university and a water works association. There should be more combined sponsorship involving those named, together with public-official agencies and local water and health departments.

There is ample reason to obtain more sponsorship of water works training by school extension services, as Michigan, Texas and Oklahoma have done.

Benefits to Trainee

In many states, short-course training is prerequisite to certification. Hence, the trainee fulfills a legal or voluntary requirement of his employment by attending. The amount of knowledge obtained by a trainee depends on several factors, such as his personal interest; his previous education; his mental capacity for learning; the encouragement he receives from his employers and his family; and the caliber of training offered. Whatever his additional knowledge, the enrollee will absorb a new enthusiasm for his work; increase his contacts with people and literature; add to his sources of data; develop a better understanding of his duties and responsibilities; and appreciate the position of state and local agencies with which water supply officials have contact.

Management Expectations

Management wants qualified men at work. However, the word "qualified" must be defined. When either voluntary or mandatory certification exists, management can feel reassured in hiring a certified man. Management expects increased proficiency in operators with short-course training but generally does not recognize it as a substitute for the broader scientific training required of engineers, chemists and other personnel who must manage, direct or perform the more complex operations of water treatment. The minority must be mentioned, however. There have been occasions when management has considered a five-day short course sufficient background to operate a plant.

Management has supported short-course training by allowing time, and often expenses, to operators and super-

TABLE 1

Report of Water Works Short Course Training in 1947

Item	No. of States
1. *States replying**	41
2. *States with training*	16
3. *States with no training*	25
	No. of Schools
4. *Sponsors*	
State health dept.	23
Local health dept.	0
Public-official agency	2
Water works organization	19
University	18
Local water dept.	1
(*Total schools*—24†)	
5. *Location of schools*	
University	14
Other	11
6. *Duration of schools*	
DAYS	
1	4
2	4
3	5
4	3
5	4
9	1
15	1
25	1
unknown	1
7. *Frequency of courses*	
Semiannual	2
Annual	18
Biennial	2
Unknown	2
8. *Geographical basis*	
Statewide	15
Regional‡	8
Local	1
9. *Cost of registration*	
$ 0.00	7
1.00	1
2.00	3
5.00	3
7.50	2
15.00	1
50.00	1
unknown	6
10. *Type of student*	
Operator	23
Superintendent	21
Manager	8
Consultant	7
Public health agency employee	7
Miscellaneous	11
(*Total students*—2,422§)	

* As of May 3, 1948.

† Six states have two schools and one state has three, making a total of 24 schools in all. Because of multiple sponsorship, the number of schools listed in Item 4 exceeds the actual total.

‡ Where a series of regional schools was held, as in Oregon, Kentucky and Tennessee, this has been counted as one in the tabulation.

§ Not including four states for which this information is lacking.

intendents in order that they could attend the training sessions. But a minority considers short courses as a junket or a vacation and refuses to believe that the money expended for training returns to the city in better water system maintenance.

Inter-agency Relationships

The state health department has ample motive, and in some states legal compulsion, to sponsor training courses leading to the certification of water works operators. Both advanced and basic training in the sciences require the facilities of technical schools; therefore, university participation is essential. Public-official agencies which are interested in stretching the municipal dollar to cover the best in water supply have an interest in the training that their water works officials receive. Both state and national water works and public health associations have a professional interest in the improvement of water systems and, consequently, in the men who run them and who make up the association membership. The national associations, such as the A.W.W.A. and the A.P.H.A., have an additional interest in the development of a policy and program that will lead to uniform training standards. There is also the matter of reciprocity between states. If training standards are uniform, training obtained in one state should be acceptable as the basis for certification in another state.

Local health and water departments can be extremely useful in some phases of training, such as preservice and inservice training and on-the-job advice.

All of the above agencies have responsible parts to play. Coordination of effort and cooperation of all must be effected. A possible pattern for coordination might be one discussed at a conference on field training in public health held in Washington, D.C., in April 1948. This pattern, shaped to water works training, could be outlined thus:

1. *Planning and policy:* State health department, U.S. Public Health Service, national and state associations and universities concerned
2. *Operation:* State health department, local water works and health departments and schools
3. *Financing:* State health department, federal agency, schools, public-official agencies, local water departments and individuals
4. *Evaluation:* State health department, state associations, local health and water departments and schools
5. *Specific program content:* State health department, local health and water departments and schools
6. *Accreditation:* National associations concerned
7. *Sponsorship:* State associations concerned, schools, public-official agencies, state health departments and local health and water departments.

Since the state health department is included in most of the coordinating work, it quite logically should take the initiative and serve as a coordinator of training within a state. The development of national policy, the establishment of uniform training standards and the determination of some basis for recognizing the quality of training, such as accreditation, should be coordinated by the national association concerned.

Emphasis on Water Treatment

In many of the first short courses sponsored by state health departments,

treatment rather than distribution was emphasized because the former was the area of work over which the health department had direct control. However, the content of 1947 courses indicates a growing appreciation of other problems of operation and maintenance. Multiple sponsorship has injected various viewpoints, and one finds a breadth of training more in keeping with the need. For instance, the North Carolina school had sessions on corrosion control, hydraulics and pumps, in addition to water treatment subjects. The Rutgers University course devoted one-third of the training time to distribution problems.

Content of Program

A training program must recognize that there is a complete system from the source of supply to the ultimate consumer tap which must be operated and maintained in the best condition. Although some operators of small systems are responsible for every phase of operation, many water works men are concerned only with specific portions of a system, such as the source and intake works, treatment works, transmission lines or the distribution system. The varying interests and needs involved in particular jobs must be recognized in the development of course content. Since one short school cannot cover everything, some have provided a series of specialized courses. For example, Michigan has separate five-day courses on the fundamentals of mathematics and chemistry; chemical laboratory tests; bacteriological laboratory tests; hydraulics; and methods of operation and maintenance. During a span of years an operator can complete each of the courses in which he has an interest. Minnesota is also following the specialization plan to some extent; in 1947 the entire course was devoted to a study of the piping system.

The problem of individual background must be considered. A person with a high school education cannot absorb as much from a short course on iron removal or hydraulics as would a graduate chemist or engineer. Course content must be tailored to meet the needs of the operators. It follows logically that there must be several different kinds of training, which can be classified as basic academic training; orientation or preservice training for new employees; in-service training to make advancement possible within an organization; extension training in such fundamentals as mathematics and water biology to fill the gaps in the student's academic background; and short-course training for broadening perspective and for gaining new information on specific problems.

Effectiveness of Courses

Time away from work and travel distances are obstacles to centralized short-course training. On the other hand, it has already been found that certain types of training are effective only when university facilities are used. Well-planned courses under competent direction, given by instructors trained in teaching methods and held at places where satisfactory training facilities are available, have been successful for those who can get away from work. Extension courses given on a regional basis at night or on Saturdays have also been successful. Localized courses of short duration given by itinerant instructors offer the small water system operator an opportunity for training he would not otherwise have. Day-to-day instruction and advice by water works superintendents and sanitary engineers in local health departments

present opportunities to the man who cannot leave his work.

It appears that each type of instruction is valuable and appropriate in certain circumstances. The use of itinerant instructors and local health and water department personnel needs further development. Though the procedures are less spectacular, these local officials have produced, and can continue to produce, worth-while and enduring improvements in the proficiency of water works operators.

It is reemphasized that short course training is supplemental to basic training in fundamentals. There is no good substitute for certain essential training received academically.

Influence of State Laws

Mandatory certification or approval of operators by some state agency has a direct bearing on attendance at schools. The requirement of certification to obtain a job is a compelling force recognized by public officials and water works employees. On the other hand, voluntary certification has created a real interest. Many operators and municipal officials realize that there is value in training which leads to a certificate. Hence, support is given to the training courses.

It is beneficial for water works training programs to have official status, since it dignifies the program in the eyes of the public, provides a basis for subsidies and payment of individual expenses, and gives legal backing to the personnel who plan and carry out the training.

Conclusion

Short-course training programs were reported in 1947 by 39 per cent of the states. More than 2,400 persons received training in courses given on a statewide, regional or community basis. The sponsorship of schools is dependent on many factors. The usual pattern has been a combined sponsorship by the state health department, a university and the state water works association.

The state health department is the logical coordinator of training within the state. The national professional association is the logical coordinator of national policy on the development of uniform training standards and the establishment of some basis for recognizing the quality of training. The cooperation of public-official agencies, universities, local health and water departments and professional associations should be obtained. Several kinds of training programs are needed. These include basic academic training, orientation or preservice training, in-service training, extension-course training and formal short-course training. Courses should be developed according to uniform standards to meet the needs of individuals of varying backgrounds.

Courses should be given centrally, regionally or locally as may be necessary to reach all operating personnel.

Legal status for certification is helpful in the development and teaching of training courses for water works operators.

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Supplementary training has grown in late years to be almost a necessity in all professions. It is needed to help keep professional men abreast of an ever changing technological world. For subprofessionals, such as apprentices in water treatment and control,

supplementary training may be used as a means of raising their educational qualifications to comply with governmental licensing requirements.

In Michigan an attempt has been made to provide training for all classes of operators (there are seven classifications in Michigan). Three separate educational opportunities are offered, the first of which was established in 1933, two years after the adoption of a regulation by the Michigan Dept. of Health requiring certification of water treatment plant operators. The school was established at Michigan State College, at the suggestion of the Michigan Conference on Water Purification and the State Dept. of Health, after it was recognized that many operators needed practical laboratory training in chemistry and bacteriology to qualify for certification. The course originally offered was of three days' duration and was held during the same week as the conference, the two events thus providing one full week of activity.

Special Courses

In 1947 this special course was completely revised to permit more complete coverage of the subject. Lectures were added to the laboratory phases. In addition, water and sewage plant personnel were grouped together for common instruction in both fields, in order to give each student a broader background. The school now comprises five independent courses, each of one week's duration.

In the first week the fundamentals of mathematics and chemistry are studied as they apply to water supply and sewage disposal, and a survey is made of the field of water and sewage treatment. The object of this course is to increase the fundamental knowledge of those students whose training has been limited, in order that they can better understand the work in subsequent periods and apply this knowledge to their jobs.

The subject matter in the study of mathematics includes: the use of fractions and decimals and the calculation of percentages; the metric system; proportions; elementary algebra; and some applied geometry and trigonometry. The material is supplemented by problems involving calculations of chemical feed rates; tank capacities; filter, pumping and flow rates; percentage efficiencies; and electrical measurements.

The study of chemistry includes a discussion of atoms, molecules, atomic weights, chemical equations, valence, standard solutions and the chemical reactions encountered in water and sewage treatment and in laboratory control tests.

The survey involves a general discussion, in outline form, of water supply and sewage disposal, including the major processes of treatment, such as coagulation, sedimentation, filtration, chlorination, taste and odor control, red water, corrosion, softening, fluorides, sewage collection, screening, grit collection, settling, sludge digestion and disposal, chemical treatment, biological filtration and activated sludge.

The object of the second week's course is to familiarize the student with the chemical laboratory tests commonly used in the control of water and sewage treatment processes.

Demonstration tests are made by the instructor to indicate the technique involved, after which the student performs individually a certain limited number of tests. The results of these tests are interepreted from the stand-

point of plant control and the determination of plant efficiencies. The tests made are for: alkalinity, hardness, magnesium, chlorine (free and combined), total and suspended solids, B.O.D., pH and sludge volatile matter.

The third week covers bacteriological tests involved in water supply and sewage disposal. This course includes a series of laboratory tests made by each student for the bacterial analysis of water and sewage. Lectures are given to describe the technique and to interpret the results. United States Public Health Service standards are discussed.

In the fourth week a study is made of the fundamentals of water and sewage flow and the factors affecting this flow (hydraulics). The course includes rates of flow, friction or loss of head, coefficients, the use of flow charts, devices for measuring flow, capacities of wells, drawdown and pump capacities and ratings.

The fifth week is devoted to a study of methods of operation and maintenance of water supply and sewage disposal facilities. This course includes discussions of structures and equipment used in these facilities; proper methods of operation and control; and operation records.

Considerable time is given to the preventive maintenance of the structures and equipment. The subjects covered are: paints for concrete or metal; corrosion control; oils and grease; proper maintenance procedures and time intervals between these operations; and maintenance records. Some of this material is presented by operators or equipment manufacturers' representatives.

The examining board for certification of water treatment plant operators has always recognized the value of these special courses and has allowed certain credits in the educational category for the completion of each week's work.

The school is now sponsored by the Michigan Section, A.W.W.A.; the Michigan Sewage Works Assn.; the Michigan Dept. of Health; and the School of Engineering and the Dept. of Bacteriology of Michigan State College.

Since its inception the school has been under the guidance and instruction of E. F. Eldridge, Frank R. Theroux and W. L. Mallmann, the authors of the text (1) used in the course.

A registration fee of $2.00 is required.

Extension Courses

The second course of instruction offered to water works personnel in Michigan was developed at the insistence of the operators for some academic homework. It was thought that correspondence courses would be suitable, but on consulting educational authorities at the University of Michigan, Michigan State College and Wayne University, the Education Committee was informed that technical subjects could best be taught by an instructor. The university authorities suggested extension courses and, surprisingly enough, were willing to provide them. As finally worked out, one noncredit course of study was given each winter or spring term at the following cities: Ann Arbor, Detroit, Saginaw, Grand Rapids, Lansing, Battle Creek and Kalamazoo. The courses lasted sixteen weeks and consisted of a two-hour class one night a week. The extension classes were started in 1945 and since then the

courses of study have rotated among the cities. The courses offered have included: Water Bacteriology, Chemistry Applied to Water Purification (Course I and II), Hydraulics, Fresh Water Biology (Course I and II) and Water Works Engineering.

Instruction is always given by well-known college professors, except for Course I in chemistry and in biology, where instructors are used to prepare the student for the second course in each subject.

The extension courses are sponsored by the Michigan Section, A.W.W.A.; the School of Engineering and the Extension Dept. of the University of Michigan; the Extension Div. of Michigan State College; and the State Board of Control of Vocational Education. During the past year the Michigan Sewage Works Assn. also joined in the sponsorship and was largely instrumental in the adoption of a new course on Industrial Wastes and Stream Pollution Problems. Professor Earnest Boyce, Chairman, Dept. of Civil Engineering, University of Michigan, has aided immeasurably in making these courses successful.

Course fees range from $5.00 to $7.50, and the cost of books is an additional charge.

A sample description of one of the extension courses may be of interest:

Fresh Water Biology. Course II. Fresh water biology designed for persons with some previous knowledge of the techniques of sampling and microscopic examination. (Equivalent to the instruction given in Course I.) This course includes a study of algae and higher forms of life in water. Also aquatic ecology of lakes and streams with stress on physical, chemical and biological factors. A number of the afternoon sessions will be spent in the field. Instructor: Frank E. Eggleton, Assoc. Prof. of Zoology, Univ. of Michigan.

High-Level Courses

The third and final educational opportunity is unique in being strictly a high-level course. It is a two- or three-day meeting, which thus far has been held every second year. A special faculty is brought together to discuss particular technical problems in the water works field, at a postgraduate level. Usually only one subject is assigned to a day At the first supplementary training course for water works personnel in 1945 one day was allowed for each of three subjects—chlorine, iron and fluorides. Each subject is covered completely. The lectures are published and copies given to all who attend, so that the material may be used for reference.

The course is sponsored by the Michigan Section, A.W.W.A., and the School of Public Health, University of Michigan. The courses are developed and the faculty selected by the Education Committee of the Michigan Section with the help and guidance of Harry Miller, Special Lecturer, and Henry Vaughan, Dean, School of Public Health. The committee is instructed to select the best faculty that is available, and the quality of the course is therefore limited only by the ability of the committee to recognize and choose the best talent. Course fees are $5.00.

Evaluation of Program

Participation in the Water and Sewage Works Operators' Special Courses at Michigan State College is planned to provide the trainee with: (1) a practical knowledge of, and ability to

perform and interpret, routine tests in chemistry and bacteriology required in the control and operation of a public water supply, as well as a knowledge of hydraulics and of operational and maintenance methods; and (2) additional credits in the educational category to help him qualify to take the examination for certification as a water treatment plant operator, and also to help him prepare to pass the written and laboratory examinations.

Similarly, those who take the noncredit extension courses under competent instruction have an opportunity to learn, or obtain an appreciation of, certain basic subjects related to their work in the water industry. Some may use the courses to refresh their memories or to learn newer concepts or theories, but for the majority the courses provide an academic approach to subjects in which they have had some practical experience but very little theory. The extension courses also help to prepare candidates for the examination for certification.

Attendance at the training course for water works personnel affords the operators an opportunity to meet and hear recognized authorities on special problems. Such contacts are stimulating and help direct the thinking of those present toward the solution of their own problems, as well as keeping them abreast of the latest findings and progress in the subjects discussed.

Training courses provide management with an opportunity to acquire qualified men for technical positions in the water treatment field. Without such courses, management would be forced to provide its own training facilities, to employ only previously trained persons, or, more likely, to try and get along with incompetent help. Management undoubtedly appreciates the results of good training courses as a means of better discharging its responsibility to the public for supplying a safe and palatable water at all times.

Cooperation between all agencies interested in training courses is essential to the success of such undertakings. It was of interest to the Education Committee of the Michigan Section that all of the Michigan schools of higher learning which were approached were anxious to help solve the water works education problems.

In the three courses given in Michigan, the emphasis is on water quality and safety, presumably because the need for special training in those subjects was more acute and better recognized. Certainly, training for distribution system personnel is desirable and important, particularly for the small-town operators, in all phases of their activities. Two of the courses offer subject material in hydraulics and water works engineering which is pertinent to distribution personnel.

The full content of a well-balanced program should include laboratory, academic and high-level training for both treatment and distribution system personnel. The outline presented earlier in this report can be used, in part, for such a program.

The effectiveness of training programs is closely related to the time required, the distance to be traveled and the expense to the participants. Laboratory courses usually require that the participants visit the college or university where facilities and instructors are available. If the school is centrally located within the state and the course requires no more than five days' time, the travel and time needed present little difficulty. Even though some of

the operators travel as much as 400 miles each way to the Michigan school, they seem to be regular in attendance each year. A school located in the Upper Peninsula of Michigan would lessen the mileage but even then the distance would only be cut in half. To afford educational opportunities to those living in sparsely settled areas is difficult and very expensive, even if correspondence courses are given.

The time at which laboratory courses are held is usually during working hours; thus management must approve before an operator can attend. Extension courses, however, are held in the evening, and the participants usually attend on their own time. The travel expense is negligible for most of the students—it is the instructor who does the traveling. The cost to the student is also kept low, because he can live at home.

It is believed that systematic training can be effectively brought to the trainee on his own job only by means of an itinerant instructor who would teach an extension course at night and spend a part of the day at the plant with the student. Such a program has the blessing of the State Board of Control of Vocational Education and of the University of Michigan. The problem is to locate and finance the teacher. To find a suitable teacher is more difficult than to finance him. Some day, however, such a solution may be employed to train water works personnel, as it has proved beneficial in other fields.

Reference

1. Theroux, Frank R.; Eldridge, Edward F.; & Mallmann, W. LeRoy. *Laboratory Manual for Chemical and Bacterial Analysis of Water and Sewage.* McGraw-Hill Book Co., New York (3rd ed., 1943).

A. P. Black

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The first of Florida's fifteen short courses on water supply and treatment was held in 1930. It was organized to meet one of the many needs of a rapidly growing state.

The urban population of Florida more than doubled between 1920 and 1930. Quiet, crossroad communities became, almost overnight, small cities full of new people from all over the nation, people who had become accustomed to municipal services which these new Florida cities had never rendered. The usual businesses which serve the public accompanied the increase in population. New hotels, stores, laundries, soft drink plants and a sprinkling of small industries were established, all of which required a water supply. There arose an immediate necessity for water plant enlargement and extensive distribution systems to meet the load. The water supply, though ample, became a subject for critical discussion. Its taste, odor and hardness were often highly objectionable. Its freedom from harmful bacteria was, in too many towns, merely hoped for, but not assured.

Boom times bring boom prices, and Florida definitely had a boom during the twenties. Numerous cities floated bonds at high interest rates and constructed plants and distribution systems at great cost. Many of these plants were well designed and adequate for the load, but their construction met the problems only in part. The new plant machinery required skilled operation, and operators were not available. Cities were reluctant to employ superintendents and operators from

outside the state at the salaries required to insure the efficiency needed. A water supply job was still viewed in many cities as a matter of turning valves and starting pumps.

Several individuals in Florida began looking into the future for the effect these water supply problems would have upon the development and health of the state. It was noted that drinking water resources which had previously been safe were rapidly becoming polluted; that the continued growth of some cities would depend upon the use of surface water with the attendant high cost of treatment plant construction; and that new plants would have to be provided with skilled operation, or continued progress would suffer.

Objectives of Program

It was agreed upon by the individuals who gave thought to these problems that education was the correct approach; that the task was not merely one of training a few operators for water plants, but also included educating the public and its elected and appointed officials in water supply problems and in the ways and means of meeting them. It was considered advisable to set forth certain objectives to be attained by any program which might be promulgated. These objectives were:

1. To educate officials and the public to the need for measures to prevent the pollution of water resources.

2. To educate officials and the public to the need for plans to utilize surface water supplies.

3. To provide plant superintendents, chemists and operators with in-service training in water treatment and distribution.

4. To develop a trained leadership in Florida in the field of water treatment and distribution.

5. To establish programs in the state institutions of higher learning to provide for major studies and research in water supply and sewerage.

It was admitted that attaining these objectives would require administration and organization by agencies interested in rendering the service. In 1930 there were three groups in Florida which were intensely desirous of beginning an immediate program of education to progress toward meeting these objectives. The General Extension Div., which represents the University of Florida and Florida State University, was empowered by state statute to carry the resources of the institutions of higher learning to the people whenever and wherever needed. The Florida State Board of Health was legally responsible for maintaining healthful conditions in the state. The Florida Section, A.W.W.A., existed for the purpose of giving advisory assistance in distributing safe and acceptable water supplies to the public. These three agencies pooled their resources to conduct the first short course on water treatment held in Florida.

The subject matter in the highly technical research papers presented during this course was beyond the grasp of many persons present. Florida has no apologies to make for this program, however. It taught the city officials and employees who attended that they had much to learn and that the water supply of a city was a service which required maximum efficiency for health and economy. It taught those responsible for the instructional program that they should take the people at their

present level of knowledge and proceed from that point.

There have been many developments in water supply and treatment education since the first short course held in 1930. Enrollments have totaled 1,380 from 116 towns. The program has developed from a two-day to a five-day course of approximately 40 hours of intensive instruction and laboratory work. In addition to the short course, other educational activities have been carried on, such as correspondence courses and regional short courses which are brought to those areas having specific water problems.

An outgrowth of this short course was the Florida Water and Sewage Works Operators Assn., organized to encourage the advancement of operators through programs of continuous training. This association initiated a voluntary system of examinations to certify water and sewage plant operators. Although there is nothing compulsory about the system, approximately 80 operators have taken these examinations each year. Municipalities are in no way committed to the employment of certified operators, but they have found that a certificate earned through these examinations is a dependable measuring device for abilities and skills. The examinations are prepared, administered and graded by an examining board twice each year. Preparation for the examinations naturally leads to study which is of benefit to the operator on his job. Although the short course provides the operator with technical knowledge helpful to him during the examination, it is not designed altogether for this purpose. The operator must have done a considerable amount of outside preparation to pass the examinations for a certificate successfully. Whether or not the examination of operators will become compulsory is a matter for the future to decide. So far, the voluntary system is receiving considerable support.

Even though short courses have been conducted since 1930, no one will contend that the training job has been or will ever be completed. Florida has had another enormous increase in its urban population. Many new plants are required, as well as extensive enlargements of old ones. More plant employees with adequate skills are needed than ever before; training and retraining of personnel must still go on. But Florida now has the organization and the personnel to meet these training needs.

Education Committee

The educational program in water supply and treatment, as now conducted in Florida, is developed by the Florida Committee on Water Supply and Sewerage Education. The scope of the committee includes instruction in the sewerage field because a short course in that subject is conducted concurrently with the one on water supply. On the committee are representatives from three colleges within the University of Florida (the General Extension Div., the College of Engineering and the College of Arts and Sciences) and one representative each from the Florida State Board of Health, the Florida Section, A.W.W.A., the Florida Water and Sewage Works Operators Assn. and the Florida Sewage Works Assn. The Chief Sanitary Engineer of the Florida State Board of Health is permanent chairman. The committee was established to "study educational needs in water supply and sewerage and to develop instructional programs to meet these

needs." The educational programs of the committee are conducted through the General Extension Div. Public Service Training Center. This agency is empowered by law, and has the organization, to coordinate state resources required for conducting statewide training programs of interest to municipalities. Florida has an Institute of Government which restricts its activities to the elected state and county officials. There is no state civil service system for municipal employees.

The committee has not found it necessary to define the scope of activity of participating organizations, each of which has a definite and important contribution to make. Neither does any single organization dominate the program. There is more to do in Florida than all of the organizations working together can ever accomplish, and a realization of this fact has contributed toward the harmonious working relationship which now exists.

The committee's most important function—and also its most difficult problem—is the development of training programs to meet the needs of individuals. Persons come to the short course with training and experience varying from many years to none. The new men must begin with fundamentals, while the others must be taught at a level which will be of interest and benefit to them. The committee therefore has to present programs on both the elementary and advanced levels.

Students at the elementary level are taught the terminology of supply and treatment, elementary water chemistry and special subjects. They are placed in laboratories where they are supervised in making the simple tests used daily at a water plant. If some of the students are not far enough advanced to work effectively at the elementary level, they are placed in small groups of from six to eight under a qualified student assistant. In this way, each student gets individual attention and instruction.

Advanced students have a program arranged with sufficient flexibility to permit them to work at their maximum capabilities in discussions and in laboratories. These students are permitted time to work on problems of vital concern to their plants, and qualified staff members are present to give them direction and assistance.

Evaluation of Program

Water works management frequently expects more training for an individual than the short course is able to provide. New employees are sometimes enrolled with no training or experience in plant operation. Some of these men have a sufficient educational background to benefit from work in the elementary water section, but others do not. The short-course method of instruction is best adapted to the intelligent and industrious individual with previous experience who desires to increase his store of knowledge at a rapid rate.

Attendance at all sessions is a strict requirement and is checked by head instructors, who are furnished class rolls. Students are graded on performance. Certificates of merit are issued only upon the recommendation of instructors.

It is not claimed that a highly skilled operator can be produced by a 40-hour program of instruction. The short course is not supposed to be a basic training activity. It is strongly contended, however, that the operator with previous experience can absorb a great deal in 40 hours if the program

is arranged so that he can "learn by doing" and "learn by seeing." It is also contended that benefits are derived from an accumulation of knowledge gained through attendance at several short courses. Many operators have attended eight or more of these programs.

The new operator should probably be trained through an in-service educational program in his home plant. Some of this work is being done by plants even though it is not called by that name. Any well qualified superintendent is able to and does train the new man. The industrious superintendent will use every resource available to train and retrain plant operators. Consultants from the state board of health, representatives of manufacturers, faculty members of universities and others are used by many cities for this purpose.

A definite program of in-service training has not been initiated in Florida, but the committee has been giving some thought to the matter. The future of these short courses in Florida is being considered by the Committee on Water Supply and Sewerage Education. There will always be new operators to train. Whether or not the four sponsoring agencies should continue their efforts to train the new operator is, at present, subject to question. Perhaps the future function of the short course may be to train the top man in the water plant and to give him assistance in developing his program of in-service training for his employees.

Florida has not given much consideration to the possibility that water quality and safety have been overemphasized. Short courses have been developed to meet pressing demands. Perhaps an examination of previous programs would support the claim of overemphasis on treatment, but Florida has problems of treatment not faced by many other states. The taste, color and odor of the water supply in many towns are still objectionable. To continue attracting a large tourist trade, Florida must double its effort to clean up its drinking water supply.

During the early days of these short courses outstanding specialists were brought into the state to lecture on water treatment and distribution. This practice has been discontinued except when such persons have specialized knowledge of certain phases of water supply and treatment about which Florida needs to be informed. Faculty members of the University of Florida, consultants employed by the State Board of Health, and some of the superintendents in the state are highly capable instructors. These men know the state, are acquainted with most of the water plant employees and have a knowledge of their problems. Representatives of plant equipment manufacturers are also used as instructors. Manufacturers have selected the highest type of representative to attend the short course. These men come not only as instructors, but also as students. They participate in the program in a very unobtrusive manner, leave their wares at home and make very splendid contributions to the instructional program. The representatives also assist in promoting attendance and in discovering the fields where training is needed.

The reading of papers in Florida short courses has been practically eliminated. Experience has proved that the student will stay for five full days of hard work in which he participates, but he can withstand no more than two days of listening. All methods of teach-

ing, both old and new, must be used if interest and enthusiasm is to be maintained during a seven-hour day of instruction.

Conclusion

There is still a tremendous job to be done in Florida on water supply and treatment education. Hopes for a corps of trained men in this field will suffer frustration without an enlightened public opinion, The people see the water only as it comes from the tap, and they are not informed of the processes which produce this clear and pure water flow. They are not conscious of the fact that untrained and inefficient plant operators can cause unimaginable difficulties for a city population; that the hard working and dependable plant operator holds one of the most important positions in the community; and that the operator stands guard with others against epidemics and fire—two serious enemies to life, property and progress.

Training programs must be enlarged to help water system employees sell themselves and their jobs to their communities. Only then will these men be given the community status they so richly deserve. This may be propaganda, but propaganda for worth-while goals is certainly desirable.

H. N. Lendall

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Beginning in 1931 water works short courses offered in New Jersey were held annually until the outbreak of World War II; they were resumed in February 1947. The courses are of the laboratory type and consist of approximately 25 hours of lectures and discussions, 25 hours of laboratory work accompanied by lectures, and an inspection trip to near-by plants. It is the practice to give a limited number of laboratory demonstrations and have the students actually perform the standard tests. This provides some acquaintance with laboratory technique and furnishes instruction in laboratory procedures.

Prior to World War II courses were scheduled for a period of two weeks. Classes were held daily except Saturday from 9:00 A.M. to 4:30 P.M., with one hour off for lunch. Since 1947 the courses have been held on Tuesdays and Thursdays for a period of six weeks. This plan has been found to be of considerable advantage, as the men are not kept away from their jobs for a long period and have an opportunity to review work which has been given in class and in the laboratory. It also permits the scheduling of the course with much less interference with the usual duties of the faculty.

During the first few years when the courses were offered, provision was made to house the trainees on the university campus. Although at that time a few did commute, it has now become common for all in attendance to travel daily to the university. New Jersey is not a large state and the maximum round-trip distance rarely exceeds 100 miles.

Courses are offered by the College of Engineering, Rutgers University, in cooperation with the Bureau of Engineering of the New Jersey State Dept. of Health, and are sponsored by the South Jersey Assn. of Water Superintendents and the New Jersey Section, A.W.W.A. The financial responsibility for operating short courses is assumed entirely by the university. A fee of $15 is charged for enrollment and total receipts meet all the costs, in-

cluding laboratory breakage and supplies, printing and other expenses. The average attendance has been about twenty per year.

In planning a short course, it must be recognized that there is a wide variation in the educational background of water works employees. The majority of classes will be made up of men who have had a college technical education, as well as of others who have had few educational advantages. For this reason, the lectures should be presented with a minimum use of technical terms, employing rather those terms with which the water works man is familiar. Instructors should endeavor to learn the viewpoint of the operator who has had only practical experience. The interest of the student may be secured by having frequent discussion periods in which questions may be asked and individual problems presented.

Benefits of Program

The courses offered at Rutgers University have been planned to provide instruction in the fundamental principles of water works management and maintenance and filter plant operation. The course offers an opportunity for water works officials and employees to increase their knowledge of public water supply and treatment and to secure better qualifications to solve their special problems. It also affords a chance for study and review to those wishing to meet the license requirements of the New Jersey State Dept. of Health.

The benefit of short courses to the average trainee varies with his previous education, ability, ambition and earnestness in doing the assigned work and reading. Another important factor is the self-valuation of the water works man. The student who feels that he has a great deal to learn will generally get more out of a course than the one who believes that he is well equipped to handle his job. Generally speaking, it is expected that the man attending a short course will learn something, that he will become acquainted with certain textbooks, magazines and other literature, and—most important—that he will get an urge to read and study on his own.

In the past many private water companies and municipal authorities may have looked on short courses as a possible vacation for those who attend. The fact that the courses in New Jersey have been in operation for approximately fifteen years and that the majority of those in attendance have their expenses paid would indicate that this opinion is not prevalent and, further, that water works management has found that the men do receive training which has increased their usefulness and efficiency. Water works employees have frequently repeated the course a second and third time. It is believed that water works management does not expect the men who have taken these courses to return with full information about many phases of water works operation.

No academic credit is given for attendance. An informal certificate is issued to each man taking the course who has attended not less than 90 per cent of the classes. In New Jersey all treatment plant operators and water works superintendents must have licenses issued by the State Dept. of Health. These licenses are classified in accordance with the size, type and capacity of the water treatment plant and distributing system. Many water works employees take the short courses as a preparation for license examinations, and the Dept. of Health gives

some recognition to attendance at these courses.

Content of Course

In planning the content of the course, it has been customary to hold conferences and consultations with the Bureau of Engineering of the State Dept. of Health and with committees from the water works associations. Although the responsibility has rested largely on the university faculty, the close cooperation of these agencies has been of no little assistance and is very much desired.

It can be easily understood that a course outline may emphasize the treatment of water rather than the various problems of distribution. It has been the practice in New Jersey to have a somewhat flexible schedule so that emphasis may be placed on one or the other of these subjects, depending on the desires of those in attendance. This plan has worked out very satisfactorily. Generally speaking, it has been found that most of the men are interested in treatment plant operation.

To illustrate the content of a training program, the outline for the course given in February 1948 is presented below:

Sources of supply, methods of collection, water consumption (three hours)
Arithmetic computations, conversion units, capacities (six hours)
Elements of chemistry (three hours)
Elements of biology (three hours)
Supply and distribution systems (three hours)
Water quality; chemical and bacteriological standards (three hours)
Water treatment and treatment plant units (six hours)
Corrosion scale, bacterial slime, bacterial resistance with relation to distributing systems (three hours)
Water treatment, coagulation, filtration (six hours)
Corrosion control (three hours)
Chlorination, chlorinators and maintenance (at the Wallace and Tiernan Plant) (three hours)
Water analysis laboratory; standard physical, chemical, bacteriological tests (24 hours)
Water plant management problems (six hours).

This program provided for approximately 21 hours on distribution systems and about 50 hours on water treatment. This ratio is due to the fact that the majority of the men in attendance were treatment plant operators. Examinations were held at frequent intervals and a final examination was given on the next to last day. Experience has shown that the assignment of readings and problems has been very much worth while, as it serves to awaken the interest of the operator in preparing for future lectures.

Evaluation

In view of the time required for the proper presentation of the subject, the distance that the trainee must travel and the expense involved, short courses may be made more effective and of greater satisfaction to participants by carefully planning the details of the course. These should include a mimeographed outline of the course, well-prepared lectures and quiz periods, and laboratory direction sheets. Certain textbooks may be used to very considerable advantage. Books should be selected which not only meet the needs of the short course but can be read intelligently and understood easily by the student.

The question is always raised whether effective training can be

brought to the operator on his own job. In the opinion of the author, this is not a practical method of training, because individual instruction is quite expensive and anything along the line of correspondence courses is not satisfactory. Moreover, facilities should be available for laboratory work, and many water departments and treatment plants have very limited facilities or none at all.

In conclusion, the author feels that short courses are worth while and serve a very excellent purpose. They should be given with the idea of presenting the fundamentals of the subject, together with its practical applications, in such a way that the water works man may be encouraged to increase his knowledge by reading and studying. Courses given in New Jersey have been a definite help to water works men in securing their licenses and in improving their positions.

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The author's personal acquaintance with water works schools and conferences has been largely limited to three of the four states in the Southwest Section. In these states, three- to five-day annual short schools, and one-day district meetings or conferences scheduled at intervals varying from one to twelve times a year, have provided the general training program for water works men.

The annual short schools have customarily been held at the state college under its general sponsorship, with the cooperation of the association or conference of water works men in that state, the state department of health, the division of trades and industries of the state department of vocational education and the Southwest Section, A.W.W.A. The one-day district meetings or conferences have varied in sponsorship. In general, all of the groups previously mentioned have taken part in these sessions. Usually an itinerant teacher of the college extension and vocational force or representatives of the state department of health have provided counsel and assistance in formulating and presenting the programs.

Naturally, the subjects selected for the one-day district meetings held at scattered points over the state will need to be of a nonlaboratory type adapted to the limited time and facilities available. Inspection of a local plant and system may be made a valuable part of such meetings.

The amount or degree of knowledge which a trainee obtains from attendance at a short course will depend on several factors: his interest in learning, his willingness to work at and concentrate on the job of learning, his previous education and mental capacity for learning, and—last but not least—the encouragement and incentives which may be given him by his supervisors and employers and possibly even by his own wife and family.

Education is a continuing process. No individual ever becomes completely educated. There will always be an opportunity for new processes, equipment, methods and applications. That is what makes life interesting.

A few hours at a one-day district meeting or a few days at a short course will not give the trainee a complete understanding of perhaps even one small subject, but they will add to his knowledge of water purification and water system operation and will acquaint him with current testing methods and oper-

ational procedures. He will learn the fundamental principles of operation; the purposes of special instruments and equipment and how to check their measurements; and, in general, how to improve the operation of the plant or system with which he is connected. He will also learn of new processes and equipment which would increase the quality of his product and the economy of its production and delivery.

A point not to be overlooked is that an interested person attending any meeting, no matter what his previous training and experience, will absorb new enthusiasm for his work from his contacts with other men in the same field.

Management Attitude

The expectations of water works management from short course training will depend on the general knowledge, understanding and appreciation of the water works officials. In a publicly owned system, the attitude toward training will quite often vary with the size of community served.

City or community officials have sometimes believed that they could select any individual—perhaps the son or nephew of the mayor or of a councilman—send him to the state college or university for a week's water short course, and then turn him loose in the local purification plant or water system to gamble with the lives and money of the citizens. The reverse of this attitude is found where the city officials feel that the impractical professors at the college or the fault-finding state health department men cannot give their employees anything of practical application or value for their community. Still other officials—possibly with memories of their own attendance at certain conventions devoted largely to entertainment of various types—do not want to spend the city's money to send water works employees on such a "lark."

Fortunately, it appears that a growing majority of water works supervisors and city officials have a proper appreciation of the scope and value of training available for their employees through short courses and other types of supplementary training.

Colleges and universities, being engaged in the business of education, would seem to be best qualified and equipped to handle the administration of instruction, as well as a large amount of the actual teaching work to be undertaken. Personnel of state health departments can and should serve in a major counseling and assisting capacity. Organizations of public officials can furnish valuable help by publicizing and encouraging such training among the employees of their cities and by gaining state legislative support for its continuance and possible extension. Water works sections may play their part through financial support of training programs, visits of section officials to short courses and awards to groups or states for the largest percentages of approved water supplies, licensed employees, or similar measurable factors more or less dependent on employee training.

Advisory committees composed of representatives from the various groups and organizations named can furnish valuable advice on the content and operation of a training program. In addition, such committees serve an important psychological purpose in causing all the groups represented to feel that the program is actually their own and is not "spoon fed" to them by those not really acquainted with what needs to be accomplished.

It is undoubtedly true that in the past the major emphasis in many short courses has been on the problems of water quality and water purification. This might possibly have resulted from the influence of state health departments, whose interest naturally leans more to the sanitary quality of the water than to the economic factors involved. Modern short courses and conferences should, and generally do, provide training covering the complete field of water collection, purification and distribution.

Types of Training

A well-balanced program for training officials and employees of public water supply systems should cover the entire field of activity in providing a safe water at the most reasonable cost to the consumers. It should be planned, as far as possible, to fit the needs of trainees with various levels of education. In developing a training program the manner of conducting it should also be kept in mind. For example, certain subjects, such as basic courses in mathematics and science, can best be taught in local night classes. Others more susceptible to presentation by ordinary classroom or conference methods may be dealt with at one-day district meetings. Some subjects, particularly those involving laboratory demonstrations and the actual use of equipment by the trainee, can best be covered by short courses held at colleges or universities, where facilities for such instruction are available.

Training programs lasting for a period of several years have been tried, but changing personnel in the water departments with new men desiring training furnishes one of the difficulties in carrying out a long-range program.

The provision of training for the personnel of large departments involves no special difficulty. These employees can be allowed time to attend courses at home or away while other workers substitute for them temporarily. Such departments can also easily bear the financial burden of reimbursing the employees for expenses incurred.

In the smaller communities, with only a few employees—possibly a single individual—and the total department income limited, the provision of effective training economically becomes next to impossible.

Systematic and effective training can be brought to the trainee on his own job in various ways. Local night classes may be organized where several individuals are interested in a common subject, such as mathematics, basic science or chemistry. Classrooms and laboratories of the local high school can usually be found available. Partial reimbursement of the teacher of such classes may often be made from vocational education funds.

In large systems, classes may be organized entirely within the water department. In smaller communities, classes may be formed by employees of various municipal departments. Frequently other citizens of the community are interested in obtaining additional education in basic subjects.

Correspondence courses are available for the water works man to a limited extent. Such courses fit the needs of the employee in the one-man department or plant, but satisfactory progress requires unusual will power and perseverance in the trainee.

The effect of state laws and codes—for example, the licensing of plant operators—provides a great incentive among water works officials and employees for supplementary training.

If promotions and salary are based on such licensing, an additional inducement will be furnished.

Conclusion

A great deal of good has been accomplished by water works short courses and conferences. As is always true, there is plenty of opportunity for improvement. Better planning, better organization of material, better use of visual aids and better publicity among city officials and water works men themselves will further increase the amount and effectiveness of such education.

Charles R. Cox

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Water works schools have formed an important part of the New York State Dept. of Health program for the supervision of public water supplies. The fact that the few recent outbreaks of water-borne diseases have not been due to the lack of knowledge of technical procedures but rather to the failure to apply such procedures, or else to negligence, focuses attention upon the need for improved operation and supervision of public water supplies. As half the water supplies in the state serve populations of 1,000 or less, it is evident that local technical control of many supplies is not feasible. Therefore, starting in 1931, schools for water treatment plant operators have been held to provide instruction in the protection of the sources of water supply, the operation of water treatment plants and the laboratory control of water filtration plants.

Subsequently, to foster the employment of trained and experienced operators, as well as to discourage the discharge of qualified operators for political reasons, the Public Health Law was amended to declare operators of water purification and sewage treatment plants to be "public health personnel." In 1937 Chapter XI of the Sanitary Code was enacted to specify the qualifications for such operators. These regulations have served to stabilize personnel and to form the means of integrating local civil service into the Health Dept. program.

Sponsoring Agencies

Schools for water treatment plant operators have been sponsored in New York State by the State Dept. of Health; the Conference of Mayors and Other Municipal Officials, through its "Municipal Training Institute"; the Bureau of Public Service Training of the New York State Dept. of Education; the Association of Towns of the State of New York; and the New York Section, A.W.W.A. The State Dept. of Health, assisted by local water supply officials, furnishes technical instruction; and the Municipal Training Institute handles the clerical work, and, through the Conference of Mayors and Other Municipal Officials, secures the support of local government officials for these schools. During the war the Bureau of Public Service Training assisted the State War Council in supervising training programs, including the "Mutual Aid Plan for Water Service." It may be that the bureau will be reorganized as an institute for the training of government employees.

Trainees attending these courses have been benefited in several ways: (1) they have received technical instruction to supplement available reading material; (2) they have been given the opportunity to ask questions and to clarify their understanding of various

subjects; (3) they have received the stimulus of contact with other operators; (4) their general attitude toward their work has been improved by a greater breadth of understanding and appreciation of their duties and responsibilities; and (5) they have obtained a more comprehensive knowledge of the state agencies having contact with local water supply officials.

Water works management undoubtedly expects broader training in the operation of public water supply systems than can actually be given at short schools sponsored by state departments of health. The limitation of time even makes it necessary to curtail a discussion of those aspects of operation which directly affect the quality of the water delivered to the public. A broader approach is certainly desirable and the program of instruction should be expanded. It is likely that state agencies will continue to bear the brunt of this activity. Advanced training in the laboratory control of water filtration plants, however, necessitates the use of the facilities of technical schools, and their active participation is essential to the program. In-service training, following attendance at short schools, and the holding of group meetings of neighboring water works officials can be fostered by sections of the A.W.W.A., working in cooperation with government officials.

In New York, the official state agencies have assumed the initiative in organizing training programs. This practice is basically sound when training leads to certificates of qualifications, licenses or other official documents which are associated with civil service status. In other states, sections of the A.W.W.A. or local water works organizations have conducted such schools with the assistance of state agencies.

It seems proper that the minimum training required for certificates or licenses should be conducted by official state agencies. More extended training—such as correspondence courses—in fields of water supply not of direct concern to state agencies might well be organized by associations of water works officials.

Training Program

Problems of water quality and safety may have been overemphasized as compared to problems of hydraulics, economics or office procedure, but due weight has been given in recent years to the distribution of water of safe sanitary quality through the prevention of secondary pollution and the like.

A well-balanced training program for water works employees should embrace the whole system from the source of supply to the tap of the ultimate consumer and should include public relations, office procedure, hydraulics and other basic subjects which, of necessity, have been disregarded in short-term water works training courses organized by state departments of health. Unfortunately no textbook is available in this all-inclusive field except such general publications as the "Manual for Water Works Operators" of the Texas Water Works Short School.

It is evident that the very extensive field of water supply information cannot be covered in any short school. Correspondence courses or their equivalent might, however, be conducted by sections of the A.W.W.A. or by official training institutes with full-time faculties.

No difficulty has been experienced in having water companies and municipalities pay the expenses of those attending a school of three days' duration; that is, schools for Grade III op-

erators of water chlorination plants and small-size sewage treatment plants. The time away from duty and the cost of attending Grade II schools of two weeks' duration are serious handicaps. Even if the funds and time were available, longer courses could not be given by the faculty of most technical schools. Therefore, the trend in New York State is to organize four-hour courses on Saturday mornings for 30 weeks, a total of 120 hours. Experience to date at Niagara University has shown that students will travel 75–100 miles to such schools on Saturday morning, and that their routine duties during the remainder of the week encourage freedom from the worry common to high-pressure courses. The expanded schedule also provides the students time for reflection and encourages the attendance of busy operators.

In-service training is necessary following attendance at a short school. It would seem quite difficult, however, to provide for the in-service training of individuals who have not previously attended a short school, because it is very hard to give basic training to individuals in the atmosphere of a local water purification plant. The need is so acute, however, that short schools should be supplemented with organized in-service training by a field staff or a correspondence school conducted by full-time training personnel.

Effect of State Laws

Laws and codes giving an official stamp to training programs by state departments of health, are beneficial because: (1) questions of expense and attendance at schools during working periods are clarified; (2) the organization of training personnel on the staff of state agencies gives official recognition to training programs and qualifications associated with civil service status; (3) the whole program is dignified in the eyes of the public and the taxpayer.

Solids-Contact Process Basins

By H. O. Hartung

This statement is a consolidation of the following papers presented on May 3, 1948, at the Annual Conference, Atlantic City, N.J.: "Experiences With Short-Period Flocculation and Upflow Clarification" by R. W. Haywood Jr., Asst. San. Engr., American Viscose Corp., Philadelphia; "Short-Period Flocculation and Clarifier Basins" by C. F. Wertz, Resident Engr., Dept of Water and Sewers, Miami, Fla.; and discussions by S. B. Applebaum, Pres., Liquid Conditioning Corp., Linden, N.J., and H. O. Hartung, Production Engr., St. Louis County Water Co., St. Louis, Mo. In the interest of economy of space and continuity of thought, H. O. Hartung, Chairman, Committee on Capacity and Loadings of Water Treatment Processes, was asked to prepare this digest.

THE A.W.W.A. Committee on Capacity and Loadings of Water Treatment Processes is engaged in a study of the characteristics and performances of the Accelator, * Hydrotreator † and Precipitator ‡ type of basins. R. W. Haywood, C. F. Wertz and S. B. Applebaum have made appreciable contributions to this study through their papers presented at the 1948 Annual Conference. Others have also directly aided the committee study; particularly, George A. McBride, of Infilco Inc., Chicago, and the various state sanitary and consulting engineers who completed a questionnaire mailed to them by the committee. This paper is an attempt to summarize the extent of the study at present. Those interested are invited to participate in written discussions with the committee.

Nomenclature

One of the early considerations before the committee was the need for agreement on a general descriptive name for these basins. The Accelator, Hydrotreator, Precipitator and similar water purification basins are popularly being designated in several ways. None of these names, which are discussed below, are completely descriptive of the type of flow or the purification processing which takes place within the various basins. There may be a few who will insist that the processing within each of these basins is accomplished by different means and that therefore the basins cannot be described by a single generic name; nevertheless, the basins are competitive and are generally similar in application and operation. Consequently, an overall descriptive name seems to be in order, at least for purposes of discussion.

Although the proprietary names, Accelator, Hydrotreator and Precipitator, are not necessarily descriptive in themselves, by popular usage each now connotes a particular type of basin. It might be argued that a general name for these basins need not be completely descriptive, provided its implications

* Made by Infilco, Inc., Chicago.
† Made by The Dorr Co., New York.
‡ Made by The Permutit Co., New York.

are popularly understood. A discussion of the worth of the various general names now in use will, however, further serve to characterize the basins.

Upflow Basin

The term "upflow basin" has been applied to the Accelator, Hydrotreator and Precipitator type because, loosely speaking, the water flow is vertically upward from the bottom to the top of the basin. Such a description applies more properly to the Hydrotreator than to the Accelator or Precipitator. In the Hydrotreator, water is introduced into the bottom of the basin by means of rotating distributing arms; the water then flows vertically upward into collecting troughs. In the Accelator and Precipitator, however, the water flow is both upward and downward. Moreover, the name "upflow basin" is in no sense distinctive, for it could also be applied to cold- and hot-process softeners, in which the flow is also directly upward from the bottom to the top of the tank or basin. The direction of flow is a minor characteristic of the basins, and terminology based on it completely neglects the method by which processing is accomplished within them.

It might be well to point out that the upflow rates at the sludge or slurry separation line vary between 1 and 3 gpm. per square foot, equivalent to vertical velocities of approximately 0.1 to 0.3 fpm.

Short-Period Mixing and Coagulation Basin

The designed detention time in the Accelator, Hydrotreator and Precipitator is usually between one and two hours, a relatively short period compared to the horizontal coagulation and sedimentation basin, in which the detention time often varies from about two to six hours. Detention time is not an adequate distinguishing characteristic, however, because other types of basins can have equally short detention periods.

The actual detention time in these basins has been of some interest to the committee. Table 1 lists three basins for which such data (shown in Fig. 1) have been obtained. The curves in Fig. 1 indicate that, in basins with calculated one-hour detentions, some of the flow may pass through within twenty minutes' time. The center of gravity of the area under the curve in two of the three instances is approximately the calculated detention time.

From another point of view, the period of flocculation in these basins is not "short." It is usually 30 minutes and often longer, or about the same as in many conventional flocculation chambers. A substantial portion of the time saving in the Accelator, Hydrotreator and Precipitator basins is thought to be due to the elimination of the separate basins—or basin zones—for mixing, conditioning and settling required in the conventional horizontal basins. It has been frequently claimed that an even more important time saving is realized because chemicals are usually permitted to react only in the presence of previously precipitated slurry. The reaction products are thus deposited on the surfaces of the solids, thereby saving, in some measure, the water-solids separation time required in conventional basins with a lesser-conditioned floc.

Sludge Blanket Basins

A definite characteristic of the Accelator, Hydrotreator and Precipitator basins is that water processing takes place in the presence of an apprecia-

ble amount of previously precipitated sludge. In a properly operated basin, there is a definite sludge level or line of demarcation between this sludge and the clear water, the suspended sludge being called "sludge blanket" or "slurry pool." There are some who are of the opinion that clarification and solids removal is accomplished by entrapment as the water percolates through the suspended sludge—thus the name "sludge blanket." The experience of others seems to indicate that considerable particle removal is obtained without straining or filtration through a bed of suspended solids. In some basins the sludge blanket is relatively quiescent, and in others the suspended particles are in fairly rapid motion with equal clarification results. This fact supports those who believe that the removal of solids may not be the result of any upward filtration. Because of this difference of opinion, the name "sludge blanket basin" may not be descriptive, if it implies filtration or similar mechanical entrapment of solids in the suspended solids pool.

Solids-Contact Process Basin (Reactor)

McBride and Applebaum independently have offered the term "solids contact" as being fairly descriptive of the Accelator, Hydrotreator and Precipitator. McBride has suggested "solids-contact process basin," while Applebaum has called it a "solids-contact reactor." These names take into account a very fundamental characterictic of the basins; that is, the intimate contact between the solution phase and the solid phase of the chemical reactions taking place. Yet these names are still not completely descriptive, for, as McBride points out, they do not denote any particular amount of solids or any particular manner of contact. They could be applied to sludge return or even ordinary flocculation, both of which use and depend on solids contact. The Spiractor * also employs a solids contact process but is distinctively different from the Accelator, Hydrotreator and Precipitator basins.

The committee is continuing to give consideration to a suitable general name for these basins. Suggestions from the reader will be helpful in this search.

The primary assignment before the committee is to tabulate actual basin operating experiences which will probably characterize the basins on the basis of performance. The experience

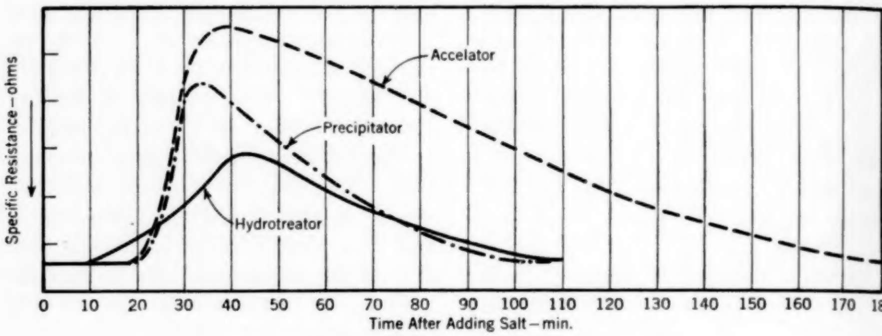

FIG. 1. Salt Detention Studies

* Made by The Permutit Co., New York

of Haywood with the "rectangular" Precipitators of the Kankakee Ordnance Works at Joliet, Ill., and of others, has been most useful to the committee in its study.

Haywood has concluded that, when basins of the Precipitator type are properly applied and their limitations recognized, they provide a definite forward step in the preparation of water for filtration. The water treatment obtained in his experience was comparable to that which would have resulted from the older arrangement of mixing, coagulation and settling in a conventional, straight-through settling basin. The three principal advantages obtained from the use of the Precipitator basin were: (1) the combination of mixing, conditioning and clarification in a single basin, resulting in a much smaller basin, per unit of capacity, than the conventional type; (2) the positive contact between the water to be clarified and an established sludge blanket; and (3) the continuous withdrawal of excess sludge, thus extending the periods of operation between shutdowns.

The Kankakee Ordnance Works installation is made up of two parallel-flow rectangular Precipitators, 35 ft. wide, 104 ft. long and 16 ft. deep. The calculated detention time in each Precipitator, based on volume, is a little less than two hours. The water from the Precipitator flows directly into a filter plant, consisting of eight filters, and then into a 300,000-gal. clear well. The experiences of Haywood at this plant may possibly indicate several general operating characteristics of this type of basin.

TABLE 1

Salt Detention Studies

Item	Accelator	Precipitator	Hydrotreator
Location	Fredericktown, Mo.	Parkville, Mo.	North Kansas City, Mo.
Flow rate, *gpm.*	312	245	2,000
Capacity, *gal.*	21,000	12,350	68,000
Detention (calcd.), *min.*	68	50	34
Center of gravity of detention curve*	73.4	50.7	52.7

* See Fig. 1.

Rapid Flow Changes

Demands for water at the plant required at times that the flow through the Precipitators be varied from approximately 75 to 100 per cent of the rated capacity more than once within an hour. The rapid change in flow resulted in unsatisfactory effluents. A change from low to high flows caused the sludge blanket to lift until the effluent from the unit had about as high a turbidity as the raw water. This condition was aggravated by the uneven distribution of sludge in the bottom of the basin, and "boils" occurred at various points, giving an effluent of even higher turbidity. Conversely, a drop from high to low flows, if followed by a low-flow period of several hours, would lower the sludge blanket concentration by allowing more solids to settle out of the field of action. Then, until the proper concentration was restored by adjusting the sludge withdrawal rates, clarification was also unsatisfactory.

When the rate of flow changed only within narrow limits, or when the change was gradual, clarification was excellent.

Applebaum, in discussing these rate-of-flow changes, pointed out that while sudden changes in rate (or "shock") should be avoided, the sludge depth and concentration is less influenced if there is good agitation over the entire bottom to keep the sludge suspended even at low rates. He concluded that the operating troubles resulting from the rapid changes of flow at the Kankakee Ordnance Works plant could have been minimized if the filter-rate controllers had been made to throttle or open gradually as the clear water level varied rather than to change the rate of flow suddenly through the entire plant.

Wertz reports that a Precipitator at the Socony Vacuum Oil Co. in East St. Louis, Ill., has been observed when the rate of flow was changed from 80 to 100 per cent in about ten minutes without any detrimental effect on effluent turbidities. This Precipitator was being used in the lime softening of a very hard water containing 14 ppm. of iron. Applebaum has pointed out, however, that the calcium carbonate and magnesium hydroxide precipitates from lime softening are relatively heavy and are less subject to carry-over.

Maintenance of Sludge Level

Operating experiences reported to the committee indicate that the maintenance of the sludge blanket at a proper level constitutes a very important requirement for satisfactory clarification in these basins. Haywood found it desirable to check the sludge level every two hours. His method was to lower a stoppered bottle on the end of a graduated rod, removing the stopper at a known depth. This operation was repeated at other depths until the top of the blanket was located. If it was too low, as indicated by a cloudy effluent, the rate of sludge withdrawal was decreased by a change in the setting of the timer controlling the draw-off valve. If the blanket was too high and solids were being carried out in the effluent, the sludge withdrawal rate was increased. Sampling lines were originally installed but soon became inoperative because of plugging.

According to information received by Wertz, Accelators at Clewiston, Fla., similarly required careful attention in order to hold the sludge blanket at a uniform level. In Pinellas County, Fla., on the other hand, no difficulty was found in holding the blanket at a uniform acceptable level while operating an Accelator at 50 per cent of its designed capacity. At Lake City, Fla., a satisfactory sludge level was maintained by employing an ammonium sulfate activated silica as a coagulant aid.

In some plants automatic sludge blowoff devices have replaced the percentage timers which open and close the sludging valve, to minimize the close attention required in maintaining sludge levels. These devices are of several types, some controlling the sludge level by a photoelectric cell and others by proportioning the amount of sludge blowoff to the rate of flow through the basins. From observations made of automatic controls, however, Wertz is of the opinion that the addition of manual control of the blowoff equipment is desirable.

Sludge withdrawal from the Precipitator at the Kankakee installation was preceded by a "flush-back" operation. "This operation," states Haywood, "was simply flushing the sludge col-

lection compartment with water under pressure for a short period immediately before opening the drawoffs, so that theoretically the sludge would be more liquid and would flow more readily through the ports in the drawoff header. It was first thought that a period of one or two minutes would be sufficient, but experience soon proved that twice or three times as much time was necessary if mounding of the sludge was to be prevented. Even with this precaution, it was necessary to empty the basins at least twice each year so that they could be thoroughly cleaned.

"At such times it was found that sludge had settled in mounds in the bottom of the sludge collection compartment and that inverted cones had formed through which all the drawing off and flushing back was being done. This, of course, contributed to improper operation of the unit [since] severe short-circuiting resulted. Changing the length of backflushing corrected these conditions to a certain extent but they were never eliminated entirely."

Rate of Mixing

Haywood has concluded that the rate of mixing and the direction of rotation of the mixing paddles in the Precipitator have no definite bearing on the water processing results. His Precipitators were provided with vari-speed, reversible motor drives. His method of study was by direct observation with the two Precipitators operating in parallel at different mixing speeds. Applebaum, on the other hand, considers the rate of mixing to be a critical performance factor in these basins, indicating that "great care in the design must be paid to the agitation so that the sludge does not settle, for, once it settles, solid deposits accumulate and interfere with operation."

Losses From Sludge Blowoff

The original Spaulding Precipitators were built with external sludge concentrators, which resulted in high sludge concentrations. Recent basins have been constructed with internal concentrators giving various degrees of sludge concentrations. Haywood's experience with an internal concentrator prompted his belief that "the removal of sludge constitutes one disadvantage [of the basin] in that a portion of the water pumped and dosed with chemical is wasted during the operation." Applebaum claims that the usual degree of thickening is about three to four times; that is, the density of the sludge in the concentrator is three to four times the density of the suspended sludge in the blanket or slurry. Based on Applebaum's figures, the sludge concentration from the average concentrator is estimated to be 1 per cent dry solids by weight.

Point of Application

According to Applebaum and others, the best basin performance is obtained when the old sludge contacts the incoming water and chemical immediately after entrance into the unit. If a chemical is added to the water before it reaches the basin, new colloidal precipitates may form that do not adhere to the old sludge nuclei. In practice, opinion is divided on which point of application is preferable. In the operation of a Hydrotreator at Weldon Springs, Mo., it was found that the addition of the lime for softening in the basin caused a sludge cementation sufficient to stop the distributing arms. This difficulty was entirely eliminated

when the lime was added to the incoming water.

Questionnaire

Because of these and other—sometimes conflicting—reports on "upflow" basin operations, the committee attempted to determine the prevalent opinion on the place of the "upflow" basin in water treatment plant flow sheets. Accordingly, a questionnaire was sent to all state sanitary and consulting engineers and to a few operators of such basins. Admittedly, the questionnaire probably had many of the faults common to this method of obtaining information. For example, the questions may not have been understood to mean the same thing by different readers. Furthermore, the person responding was not required to support his opinion with operating data. Realizing the potential weaknesses of the questionnaire, the results are submitted here without extensive interpretation.

Replies were received from 48 state departments of health, 16 consulting engineers and 9 "upflow" basin operators. Most of the replies from basin operators were referred to the committee by health department engineers. It is interesting to note that of the 48 replies from state departments of health, 19 report no "upflow" basins in use on public water supplies in the state. Six reported that only one such basin was being employed on public water supplies in their state. Moreover, the water supply officials of 27 state health departments disqualified themselves from having an opinion because they had not seen "upflow" basins in operation.

The letter of transmittal which accompanied the committee's questionnaire read:

The A.W.W.A Committee on Capacity and Loadings of Water Treatment Processes, as a part of its studies, is attempting to compile today's composite opinion of water works men as to the place of "upflow" basins in water treatment plant flow sheets. This opinion is being solicited only from those who have had a chance to observe the basins in operation, and who can be expected to be fair in their judgment. The opinion is to be today's opinion, and obviously might not agree with future opinion, as more experience and knowledge is assembled.

The enclosed questionnaire . . . does not allow for original cost considerations. Admittedly, "first cost" is very important when choosing a plant flow sheet. However, cost consideration is only important after it is determined that alternate plans will result in equal water processing performance. The questionnaire should be filled out from the point of view that comparative basin costs will be a later consideration and do not constitute a part of the question asked.

"Yes" or "No" answers to the questions will in many cases be difficult to give. Do the best you can; the questionnaire is, in the last analysis, only your today's opinion based on your observations of basins as they are in operation today.

In case you have not personally observed "upflow" basin operation, will you kindly pass the questionnaire on to the person in your organization who has had the most observation experiences.

The questions comprising the questionnaire and a summary of the answers are given below.

1. *In comparison to the design data, at what holding time, overflow rate and capacities are the "upflow" basins successfully operating?* [This question was intended to show whether the actual average flow rates through successfully operating "upflow" basins are considerably different from the publicized rates.]

Of 34 replies, 18 reported successful operation at a rate equal to the design rate, 7 indicated successful operation at 75 to 67 per cent of the design rate, 6 at 50 per cent and 3 at lower percentages.

2. *Is the effluent water from the "upflow" basins clearer, as clear as, or more turbid than could be expected from conventional settling basins?*

The majority of the 34 replies to this question stated that the clarification results from the conventional settling basin unit and the "upflow" basin were about equal. Seven reported that the effluent water from the "upflow" basin was "clearer" than could be expected from conventional settling basins, 19 indicated that the water was "as clear," and 8 replied that it was "more turbid."

3. *When softening, is the softening yield per unit of chemical added to the water greater, as great as, or poorer than could be expected from conventional flocculation and settling basins?* [This question was designed to show the importance of producing the softening reactions in the presence of previously precipitated softening sludge. Although the majority of the answers indicated that there was value in such softening, the question did not take into consideration the sludge "slurry" or "blanket" concentration in the "upflow" basins.]

Of the 24 replies, 7 indicated that the softening yield per unit of chemical added to the water was "greater" in the "upflow" basin; 15, "as great"; and 2, "poorer."

4a. *Is the water from the softening "upflow" unit chemically stable?* [In other words, are the laboratory results of the calcium carbonate stability test reproduced in the "upflow" basins, and do the "upflow" basins eliminate the necessity for chemical stabilization devices such as recarbonation?]

Out of 26 replies, 4 stated that the water was chemically stable and 22 that it was not.

4b. *If not, is the water as chemically stable as could be expected from conventional basins?*

Of the 22 persons who said that the water was not chemically stable, 7 indicated that it was "more stable" than could be expected from conventional basins; 9, "as stable"; 1, "less stable"; and 5, "don't know."

5. *Are the "upflow" units being satisfactorily used as clarification units on turbid water (turbidity greater than 750 ppm.) supplies?*

Of 20 replies, 7 reported that the "up-flow" units could be used satisfactorily as clarification units on turbid water supplies, and 13 indicated that they could not be.

6. *Is more, less or the same chemical required for equal results in treatment in the "upflow" basin than is required in the conventional flocculation and settling basins?*

The 34 replies to this question indicate that there is still considerable difference of opinion about the amount of chemical required to produce water treatment results in the "upflow" basin equal to those which can be obtained in the conventional basin. The results are inconclusive: 10 stated that "more" chemical was required in the "upflow" basin; 13, "the same"; and 11, "less."

7. *Does the "upflow" basin require more or less attention and more or less skilled operation than do conventional flocculation and settling basins?*

Of 25 replies, 20 reported that "more" attention and skill were required for the "upflow" basin than for the conventional type; 3, "the same"; and 2, "less." A few of those replying

were careful to point out that it is reasonable to expect a high-speed machine to require more attention and operating skill than a slower one.

8. *Are the "upflow" basins subject to more or fewer operating failures than are encountered in the conventional basins?*

Of 30 replies, 21 indicated that the "upflow" basin was subject to "more" failures, and 9 stated that there was "no difference." Again, a few of those replying observed that, inasmuch as a high-speed machine requires greater operating skill, it can be expected that there will be more failures whenever this requisite skill is lacking.

9. *Can the "upflow" basins be used more or less satisfactorily than conventional units on water supplies of frequently varying chemical and physical characteristics?*

Out of 35 replies, 9 indicated that the "upflow" basin was "more satisfactory"; 5, "no difference"; and 21, "less satisfactory." The answers showed that rapid changes in influent water characteristics caused operational failures in "upflow" basins.

10. *Does your state limit the installation of "upflow" equipment to any particular character or type of water?*

Of replies from 48 states, 33 reported no rules or regulations governing the use of "upflow" equipment, and 15 indicated that they discouraged or limited its use. Most of those reporting no rules or regulations stated that each proposed water supply installation or improvement was judged on its particular merits and that no specific rules existed. Some of the remaining replies indicated that there were general rules or departmental policies on settling basins which would discourage the use of "upflow" basins in some instances.

Conclusion

The replies to this opinion questionnaire appear to define the areas in "upflow" basin operation where an important difference of opinion exists. The chief value of the questionnaire lies, perhaps, in that it indicates to the committee the approach which future investigations should take.

The Committee on Capacity and Loadings of Water Treatment Processes is continuing to collect information on the experience of operators with these basins. Contributions to the committee will be greatly appreciated.

The Significance of the Bubbly Creek Experiment

By C. A. Jennings

Although chlorine had been used earlier intermittently and experimentally as a water treatment material in the United States, the work done in 1908 at Chicago and at Boonton, N.J., in effect marked the beginnings of chlorination. This paper, by C. A. Jennings, Mishawaka, Ind.—and the papers by Tiernan and Fair et al. *which follow—was presented on May 5, 1948, at a special commemorative session during the Annual Conference of the A.W.W.A. at Atlantic City, N.J.*

AFTER receiving a degree in chemistry from Purdue University at Lafayette, Ind., I spent four months with a chemical firm in Indianapolis. In October 1906 I had an opportunity to go to Chicago to enter the water purification department of the American Steel and Wire Co., a branch of the U.S. Steel Corp. At several of its wire plants, an enormous quantity of a byproduct was accumulated which had to be disposed of. This was iron sulfate, or copperas, which was produced when the iron wire was dipped into sulfuric acid for cleaning.

C. Arthur Brown, the manager of the department, had the job of finding uses for copperas. He was very active in trying to convince water purification plants to substitute iron sulfate in conjunction with lime in place of aluminum sulfate, commonly known as alum, for coagulating water. Through his contacts with the various mechanical filter companies operating in those days, Brown learned of a very acute and critical problem faced by the Union Stock Yard & Transit Co. of Chicago. This company owned the ground and the pens and buildings in the stockyards proper and was usually referred to as the "Stock Yard Co." Cattle, hogs and sheep shipped in from rural districts to the Chicago stockyards would be driven into the pens to be watered and fed until sold. It is self-evident that the more water these animals drank after arriving in the yards, the greater the weight at which they were sold and the greater the amount received by the shipper.

In 1908 and for some years earlier the water pressure in Chicago was very low, especially in the summer. Three-story apartment buildings were hard put to secure enough water on the third floors from the city mains even for sanitary purposes. The city aldermen in those days were very much opposed to meters and would hear of nothing but flat rates for water users. This attitude resulted in a very high per capita water consumption. The city could not install new water tunnels, intakes and pumping stations fast enough to keep up with the increasing demands for water and the pressure continued to drop year after year. The Stock Yard Co. had done everything it could to secure an adequate supply of city water but in vain. Consequently, the livestock suffered terribly.

There seemed no answer to the problem until somebody had the temerity to suggest that an attempt be made to

obtain drinking water from Bubbly Creek. This aptly named branch of the Chicago River had its inception at 39th and Halsted Sts., where a 20-ft. underground sewer emptied into it. The contents of the sewer came chiefly from a large section of the South Side of Chicago and flowed by gravity to a series of pumps in a pumping station at 39th Street and the lake front. These pumps elevated the sewage into the 20-ft. sewer or tunnel, which ran beneath 39th St. from the lake to Halsted St., a distance of approximately $2\frac{1}{2}$ miles. At times lake water pumped at the 39th St. station by the Sanitary Dist. was used to dilute the sewage but this practice was not at all dependable or regular.

To those who knew Bubbly Creek, the purification of its water seemed impossible. In the warmer months the surface of the water in this stream was a mass of bubbles caused by decomposition below. This would become so violent at times as to cause geysers or eruptions lasting several minutes and measuring several feet across. The material brought to the surface was as black as ink. A considerable amount of gas was given off, which was so evil smelling—especially on damp days, when the atmosphere was heavy—that it could be detected even above the prevailing odor from the stockyard pens. Chickens had been seen to venture out on the scum formed on the surface after these eruptions—and this is not exaggeration. Nearly everybody was certain that the purification scheme was a foolhardy attempt to accomplish the impossible. The reputation of Bubbly Creek as an open sewer was very widespread.

The logical approach to the solution of the purification problem was to construct an experimental filter plant. This project was carried out under the direction of the Norwood Engineering Co., of Florence, Mass., a builder of mechanical filter plants, and the Water Purification Dept. of the American Steel & Wire Co. The site chosen was the stockyard itself. I was in charge of the mechanical operation of this plant, and it was my function to establish and supervise a chemical and bacteriolgical laboratory on the premises. The effluent from this experimental plant was clear and practically odorless. The chemicals used for coagulation were iron sulfate and lime, while copper sulfate was employed as a germicide. Comparatively low bacterial counts were obtained from the discharge side of the filter. Samples for both chemical and bacteriological analysis were taken as the water came from the filters. The filtered water was not stored in a large tank or basin as is done in an operating filter plant. The importance of this detail will be evident later in this discussion.

Mechanical Filter Plant

Because the results obtained were so encouraging, the officials of the Norwood Engineering Co. and the Stock Yard Co. entered into a contract for the construction of a 5-mgd. mechanical filter plant with certain specifications as to the quality of the effluent. The plant followed the construction practices in vogue at that time, approximately three hours being required for coagulation and sedimentation, after which the water was filtered through standard rapid sand filters.

The filtered water was as beautiful to the eye as anyone could have asked. The bacteriological data on samples taken directly from the outlets of the individual filters were satisfactory. Those samples which were taken from the clear water storage basin beneath

the filters, however, showed an extremely high bacteriological count although the water remained crystal clear. Varying the amount of copper sulfate did not help, nor did changing the point or points of application. The count from the clear water basin remained high no matter what changes were made. This situation posed a critical problem. The filter company had on its hands a plant that was producing 5 mgd. of water which was clear and sparkling but did not meet the bacteriological specifications of the contract with the Stock Yard Co.

George A. Johnson, a consulting engineer of New York, was called in to help solve the difficulty. After assuring himself that apparently the copper sulfate treatment simply "stunned" the bacteria, which multiplied rapidly because of the high organic content of the water even after filtration, Johnson suggested that calcium hypochlorite be tried as a germicide. The initial results of this treatment were encouraging. However, we had had so many disappointing things happen when using copper sulfate that we proceeded cautiously. Various quantities were employed and different points of application were tried. The solution was introduced into the raw, settled and filtered water and also at more than one point at the same time. The amount of calcium hypochlorite used varied from 2.4 to as high as 4.2 ppm. After a period of some weeks, we felt that the problem had been solved. An official test run from September 3 to 17, 1908, resulted in the acceptance of this filter plant.

Having had experience with the plant from its inception, I made application for the position of chemist and superintendent, and was accepted. The Bubbly Creek installation became the first operating water purification plant in the United States to use calcium hypochlorite for disinfecting a water supply. The results were consistent and the water was used for the livestock in the pens of the Stock Yard Co.

George A. Johnson (1) stated in 1910:

> Up to 1908 the use of hypochlorites in the purification of public water supplies had not received serious consideration. Most of the information then available was fragmentary and more or less indefinite in character and the process had not gained general credence. The first demonstration in this country in a practical way of the usefulness of hypochlorites in connection with water purification was made in the fall of 1908 at the filter plant of the Chicago Stock Yards on the recommendation and under the direction of the writer.
>
> Following directly on the heels of the spectacular results obtained at Chicago, came the adoption of this process for sterilization at Boonton, N.J., of the impounded and unfiltered water supply of Jersey City. The results obtained at these two places were given wide publicity, and almost immediately the use of hypochlorites, either intermittently or continuously, spread throughout the United States.

Legal Difficulties

The city of Chicago did not sit idly by and lose the sizable revenue which the water department had been receiving from the stockyards, without putting up a fight. The city instituted a lawsuit against the Stock Yard Co. to restrain it from using this filtered and disinfected Bubbly Creek water for watering livestock. The plea was made that it constituted a health hazard to the animal handlers as they moved through the pens, inasmuch as the water would be running through open spigots into watering troughs and these men could easily be tempted to drink of it. Also there was the far-fetched claim

that harm might come to people who ate meat from livestock which had ingested this water with its high organic content. The suit took up considerable time, and much testimony was heard from sanitary engineers, chemists, medical experts and the like. When I was called on to testify in behalf of the Stock Yard Co., I stated honestly and truthfully that it had been my practice to drink the filtered water from this plant in preference to the city water. It was part of my work to make bacteriological tests of the filtered and city water several times daily, and I had substantial data to prove that, from a bacteriological standpoint, the filtered water was superior to that furnished by the city. After the conclusion of this trial, during which over 1,000 pages of testimony were taken, certain restrictions were mutually agreed upon. Signs were posted in the pens to the effect that the water was not for human consumption. However, the filtered water continued to be used for watering livestock and an enlarged storage tank was built to tide over the peak periods of water consumption in the yards. The water was also used in the fire protection system on the property of the Stock Yard Co.

An amusing incident took place on the occasion of a large dinner party staged by the American Steel & Wire Co. to celebrate the acceptance of this plant by the Stock Yard Co. In his after-dinner speech, C. Arthur Brown, who had arranged the party, drew attention to the sparklingly clear water imbibed at the dinner. Then he had carboys brought in containing samples of Bubbly Creek water before treatment. In the preparation of these sample carboys we had left nothing out, and we succeeded in making a vivid contrast between the before and after results. Brown then announced that all the water which had been served at the table was Bubbly Creek filtered water. Several of those present excused themselves hurriedly and made for the washroom.

Spread of Hypochlorite Treatment

During the early part of 1910, Alvord & Burdick, a Chicago firm of consulting engineers, received an emergency call from Erie, Pa., to advise the city officials what steps should be taken to stop a severe epidemic of typhoid fever, believed to be water-borne. Water was pumped into the city mains from Lake Erie without any treatment. I was asked by Alvord & Burdick to proceed to Erie at once and install some sort of calcium hypochlorite treatment plant for the water supply. The officials of the Stock Yard Co. very graciously consented, under the circumstances, to give me a leave of absence. In view of the real seriousness of the epidemic, no time was lost, and the most practical plant possible within a limited period was set up and put into operation. This plant consisted of a wood mixing tank mounted on top of two adjacent cypress wood storage tanks of approximately 2,500-gal. capacity each. The diluted and constantly stirred solution flowed by gravity from the storage tanks, through an adjustable orifice, into a measuring tank below. The solution was then fed into the suction of the various high-pressure water pumps. A chemical and bacteriological laboratory was set up, and a close check was kept on the quality of the water being treated, as well as on its taste. Samples were taken at many points in the city distribution system and dead ends were thoroughly flushed. The treatment plant proved successful in rendering the water supply safe and the epidemic tapered off rapidly.

A few months after this experience at Erie, I was summoned by the city officials of Pasco, Wash., for the same purpose. L. L. Lumsden, of the U.S. Public Health Service, had been called to Pasco because of an outbreak of typhoid there and his recommendation was to treat the water supply with calcium hypochlorite. The same general pattern was followed in installing an emergency treatment plant, as it was comparatively easy in those days to secure the delivery of wood tanks and other more-or-less crude materials required. After the installation at Pasco, I did work at Grant's Pass and Salem, Ore. Upon my return after four months on the Pacific Coast, in the fall of 1911, I supervised installations of similar plants in Iowa, Indiana and other states.

There were drawbacks in preparing uniform solutions of calcium hypochlorite which were due in part to the material itself. It did not go into solution readily and had to be made into a sort of mash before diluting it into a standard strength solution for the storage tanks. Also, the chemical was shipped in metal drums and its strength varied with the amount of corrosion developed in these drums. When mechanical chlorinators using liquid chlorine in place of calcium hypochlorite were introduced, they found a ready welcome. It was only natural that I should become interested in this new and practical development in the disinfection of water supplies. I soon began to handle Wallace & Tiernan chlorinators as a sideline to my position at the Bubbly Creek filter plant and continued doing this for some time. However, I eventually saw that the possibilities in chlorinator sales work were greater than in the routine operation of this now famous filter plant, and I threw in my lot with the Wallace & Tiernan Co. as their Chicago manager.

Reference

1. Johnson, George A. Hypochlorite Treatment of Public Water Supplies; Its Adaptability and Limitations. Am. Jour. Pub. Health, 1:562 (1911).

Controlling the Green Goddess

By Martin F. Tiernan

A paper presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J., by Martin F. Tiernan, Pres., Wallace & Tiernan Co., Inc., Newark, N.J.

CHLORINE (Greek: *chloros*, greenish yellow), which I am venturing to call the "Green Goddess," is a greenish-yellow gas, easily compressed to a liquid. It was discovered in 1774 by Scheele, a Swedish chemist. Well may chlorine be called the Green Goddess, because of the important place she occupies in the chemical field, and the tremendous scope of her influence and power, her ability to do good or evil for mankind and the ever increasing realm of her activity. Corrosive to practically all things, she is safe and docile when properly handled but can at times be most vexatious and dangerous to those who would woo her without an understanding and appreciation of her nature.

In dealing with the development of apparatus for controlling chlorine gas, it is necessary to mention the names and recount the experiences of many individuals who are more or less known to water works men. Should I frequently refer to the activities of my associate, C. F. Wallace, and myself, it is only because it seems pertinent to the historical record. It is always interesting to have at least a brief biographical knowledge of individuals who have been more or less prominently identified in any development work. The background of such men often explains their later activities.

Pioneers of Chlorine Control

I will speak first of E. D. Kingsley, the founder and first president of the Electro Bleaching Gas Co. In 1906 he was superintendent at the Lord & Taylor Department Store. Because of a severe operation, his doctor told him he would have to seek other employment which would enable him to keep off his feet. His nephew by marriage, a chemist named Hesse, told Kingsley of the commercial possibilities in electrifying chlorine, by which its activity could be increased. A promoter from Philadelphia persuaded Kingsley to invest $1,000 in such a scheme, which appealed to him because he appreciated the commercial value of well-bleached goods. A short time later Kingsley visited Philadelphia to check up on his investment. Learning that the individual to whom he had given the money had disappeared, Kingsley took over the company. He related his experiences to Hesse, who criticized the method of chlorine production used and advised Kingsley to go to Germany to obtain technological information.

While abroad, Kingsley observed the German method of producing chlorine. He brought back with him a German chemical engineer, imported chlorine compressing apparatus from Germany and set up the Electro Bleaching Gas Co. next to the Niagara Alkali Co. at

Niagara Falls. The name "Electro Bleaching Gas Co." derives from Kingsley's earlier contact with an electrical process which was alleged to increase the bleaching power of chlorine. Chlorine was obtained from the Niagara Alkali Co., which at that time was making chloride of lime. After considerable experimentation he succeeded in compressing about $\frac{1}{4}$ lb. of chlorine gas and this quantity stood in a small cylinder in Kingsley's office for years. I heard him relate many times that it cost $26,000. This was the first chlorine gas to be compressed in the United States. Later, the Electro Bleaching Gas Co. went into the business of compressing and selling chlorine gas commercially. It is rather interesting that a man with Kingsley's background and complete ignorance of chemical processes should find himself in this type of business. He certainly picked a "hot" one.

The minimum amount of apparatus for the introduction of chlorine into water consists of a chlorine cylinder and a valve. This is about what V. B. Nesfield (1), a lieutenant in the Indian Medical Service, described in a paper in July 1903. Chlorine gas, he wrote, was applied to water "by liquefying it [chlorine] and storing it in lead-lined iron vessels having a jet with a very fine capillary canal and fitted with a tap or a screw cap. The tap was turned on and the cylinder placed in the amount of water required. The chlorine slowly bubbled out, and in ten to fifteen minutes the water was absolutely safe, and had only to be rendered tasteless by the addition of sodium sulphite made into a cake or tablet." With our present knowledge of the art, one would hardly call this method a practical one.

Carl Darnall, doctor of medicine, was an executive officer in the U.S. Army Medical Corps. He was familiar with the Lister bag, a canvas affair used in the army to hold water for distribution to troops. Into this bag would be put chloride of lime to purify it. It occurred to Darnall to use pure chlorine gas for this purpose. As he was unable to obtain a small cylinder of the gas in this country, he sent to Germany for it. In an article (2) published in 1911 he wrote: "In June 1910, the writer began a series of experiments with the object of determining the availability of commercial liquefied chlorine for the purification of water." It seemed to have been the opinion at that time that it was necessary to have the chlorine bound up as a salt, such as chloride of lime, in order to retard the action of the element. Darnall apparently questioned that idea.

He developed an apparatus (U.S. Patent 1,007,647) for handling chlorine, consisting of a pressure-reducing mechanism, a metering device and a mixing or absorbing chamber. Other means were present for automatically starting and stopping the apparatus. Darnall installed this machine at Fort Myer, Va., and operated it for several months on a small water supply there. The chlorine was applied as a dry gas directly to the water rather than in the form of a solution. Although Darnall never entered the apparatus field commercially, he did install one unit at Youngstown, Ohio. To my mind, there is no doubt that he should receive full credit for the introduction of the use of chlorine gas in the sanitary field. I believe it was his work which aroused the interest of men like George Ornstein; John Kienle, of Wilmington, Del.; Seth Van Loan, of Philadelphia;

and D. D. Jackson, of New York. Wallace and myself were certainly indebted to Darnall.

In the application of liquid chlorine at Philadelphia in September 1912, by Seth Van Loan, an engineer in the Water Department, no special apparatus was employed. He placed the chlorine cylinders on a set of platform scales and attempted to valve the chlorine so as to get a constant loss of weight (3). The chlorine was applied directly to the water.

In December 1912 John Kienle (4), an engineer in the Water Dept. at Wilmington, Del., fed the chlorine from the cylinder to an absorption tower, through which a counterflow of water was run and the chlorine added in the form of a solution. No control mechanism other than the valve on the cylinder was used.

D. D. Jackson (5), Prof. of Chem. Eng. at Columbia University, and prior to that Director of the Mount Prospect Laboratories for the Brooklyn, N.Y., Water Dept., learning of Darnall's work, and having seen his installation at Youngstown, Ohio, started development operations in 1912—in conjunction with Frank Leavitt, Chief Engr., Bliss Co., Brooklyn, N.Y.—on a chlorine control apparatus involving the loss-of-weight principle. A chlorine cylinder was suspended on the end of a balanced beam and mechanically moved along at a predetermined rate. The movement of the beam when out of balance would either increase or decrease the rate of flow of chlorine. This apparatus (U.S. Patents 1,087,958 and 1,088,232) was known as the Leavitt-Jackson chlorinator and applied the chlorine directly to the water the same as Darnall's. Only a very small number of these machines were installed and they were soon taken off the market.

George Ornstein, a German scientist, came to America about 1909 and located in Niagara Falls, N.Y. He worked with the Hooker Electro-Chemical Co. and in 1910 joined the staff of the Electro Bleaching Gas Co., helping Kingsley in the manufacture of chlorine. Toward the latter part of 1912 Ornstein started experiments at the plant of the Western New York Water Co., where Harry Huy was superintendent, to determine the comparative efficiency of chlorine gas and chloride of lime. These experiments corroborated Darnall's results.

Following Kienle's experiments at Wilmington, Ornstein developed an apparatus (U.S. Patent 1,142,361) consisting of a high- and low-pressure gage, the latter being calibrated to indicate the flow of gas through a fixed orifice. The gas was then led into a scrubbing tower, where it was dissolved and made into a solution. This apparatus was installed at Kienle's Wilmington plant and was the first practical solution-feed machine operated in the United States. This method of applying chlorine gas came into quite general use throughout the country.

Ornstein developed an automatic apparatus (U.S. Patents 1,944,803–4) at the end of 1913, but it was never widely adopted.

Association With Wallace

The association between C. F. Wallace and myself began in New York about the middle of 1909. Wallace, an electrical engineer with practical experience—which started with digging post holes for telephone lines—got a job with the Gerard Ozone Process Co., a manufacturer of machinery for

producing ozone. I came to New York about two weeks before Wallace's arrival, from Pittsburgh, where I did laboratory work for the Pittsburgh Typhoid Fever Commission. The Gerard Co. hired me as a chemist. I had graduated from the University of Rochester in 1906 and my first job was at the Rochester Water Works on a reservoir job. Wallace and I lived together in New York and this was the beginning of an association which is now of nearly 40 years duration.

The ozone business folded up and Wallace and I joined the Moore Filter Co., an outfit making vacuum filters used in mining processes. I was sent to Mexico to install some special equipment in a mine. I was paid $5.00 a day and expenses and had managed to save up $1,000 when I returned about nine months later.

About the middle of 1911 I was let out of the Moore Co. and very shortly afterward Wallace followed. This probably was the most fortunate thing that could have happened to us. With my $1,000 and $800 that Wallace had saved, we decided to go into business for ourselves. We hired a small room in a loft building in downtown New York, spent three or four hundred dollars for second-hand tools and started in business. I had been doing work for the firm of Charles E. North and E. B. Phelps, consulting sanitarians, in New York, and any odd dollars that I picked up here and there I turned in to our partnership.

In September 1911 a severe epidemic of typhoid fever broke out in Torrington, Conn. Phelps was called in on the job and sent for me to install an emergency hypochlorite plant. Using barrels and odds and ends, I put it in operation. Later on, we (Wallace & Tiernan) made special calibrated orifices, float boxes, and the like for this plant and sold odd ones in other places.

At Torrington, I made the acquaintance of James A. Newlands, State Sanitary Engineer, whose name will be mentioned later on. The Torrington Water Co. kept me on until April 1912, when I returned to New York and picked up other free-lance jobs when I wasn't working with Wallace in our shop. At that time we had one employee, who, by the way, is still with us. We developed various gadgets for handling hypochlorite solutions, and such items as orifices that might be used in experimental work. In the early fall of 1912 I spent about six weeks operating the hypochlorite plant for the Jersey City Water Dept. at Boonton, N.J., the chemist having gone on vacation. This background gave me pretty good experience in the hypochlorite picture.

I had previously learned that Darnall was working on the idea of using dry chlorine gas for water sterilization. Intrigued, I visited Darnall in Washington, where he told me of his work and gave me a copy of a paper (2) he had published a year or so before. He had a small apparatus in the corner of his office, substantially the same as described in his article.

Dover Hypochlorite Plant

That fall William Griffin, the superintendent of the Jersey City Water Dept., was considering the installation of a hypochlorite plant at Dover, N. J., to treat a Rockaway River tributary which fed the Boonton reservoir. I suggested the use of chlorine gas to Griffin and he asked me to look into the matter. Griffin and I visited the office of the Electro Bleaching Gas Co.

to see if chlorine was available, and I went to Niagara Falls to interview Ornstein. He took me over to the plant of the Niagara Falls Water Co., where Harry Huy was superintendent and where a method of making chlorine solution from chlorine gas was employed. The solution was made up in a tank from which it was fed by an orifice. The bacteriological results of Darnall and the Niagara Falls Plant compared very favorably with those obtained from hypochlorite.

I reported to Griffin that I thought a chlorine gas plant was the thing to install at Dover. As there was no water under pressure, a direct-feed apparatus had to be used. Wallace and I made a proposal to Jersey City to install such a plant, with guarantees as to operation, for the sum of $150. At that time we hadn't even designed the apparatus.

We secured a cylinder of chlorine from the Pennsylvania Salt Co. and started on the apparatus. We entered into the program full of enthusiasm but ignorant of the properties of compressed chlorine gas. Had we suspected the difficulties before us we probably never would have attempted this activity.

The first apparatus used hard rubber parts, in contact with the chlorine, and ordinary solder for joints of metal tubing. When subjected to chlorine under pressure it literally blew up in our faces. After many tries, we produced a controlling mechanism which, under a short test in our shop, seemed to be all right, and we arranged to install it at Dover. The apparatus was put on the wall in the pattern shop of the McKernan Drill Works, which happened to be located on the edge of the Rockaway River tributary, and had a lot of nice bright, shiny tools. To effect the solution of the gas in the stream, we put an inverted trough across the stream bottom, weighing it down with stones, and introduced the gas at one end of the trough. Inasmuch as this water was a tributary to a drinking water supply, it was necessary to get the approval of the New Jersey State Board of Health. Fitz Randolph, the director, was present to inspect the installation when the gas was turned on. A considerable portion of the gas came to the surface of the water, but a good strong breeze diluted it so that Randolph got just a very slight odor. He said, "That smells okay and the installation seems to be in order."

We left the apparatus turned on and returned to New York. The next morning when we entered our shop the phone was ringing. The McKernan Drill people wanted to know what we were trying to do up there. The apparatus had sprung a leak during the night, all the tools in the shop were coated with rust, and they had promptly thrown the device out the window.

We redesigned the apparatus and made diffusors out of small Alundum grinding wheels, cemented into the saucer of a flower pot. We had a small house built on the bank of the stream, made the installation and anchored the diffusors to the bottom of the stream, where the gas was led, first through hard rubber tubing and later through silver tubing. We completed the installation on February 22, 1913. The meter was a volumetric inverted-syphon type, which we are still using. The apparatus gave satisfactory service for a good many years. Figure 1 is a photograph of the chlorinator.

Other Early Installations

A second installation of this kind was made at Fords Pond, on another

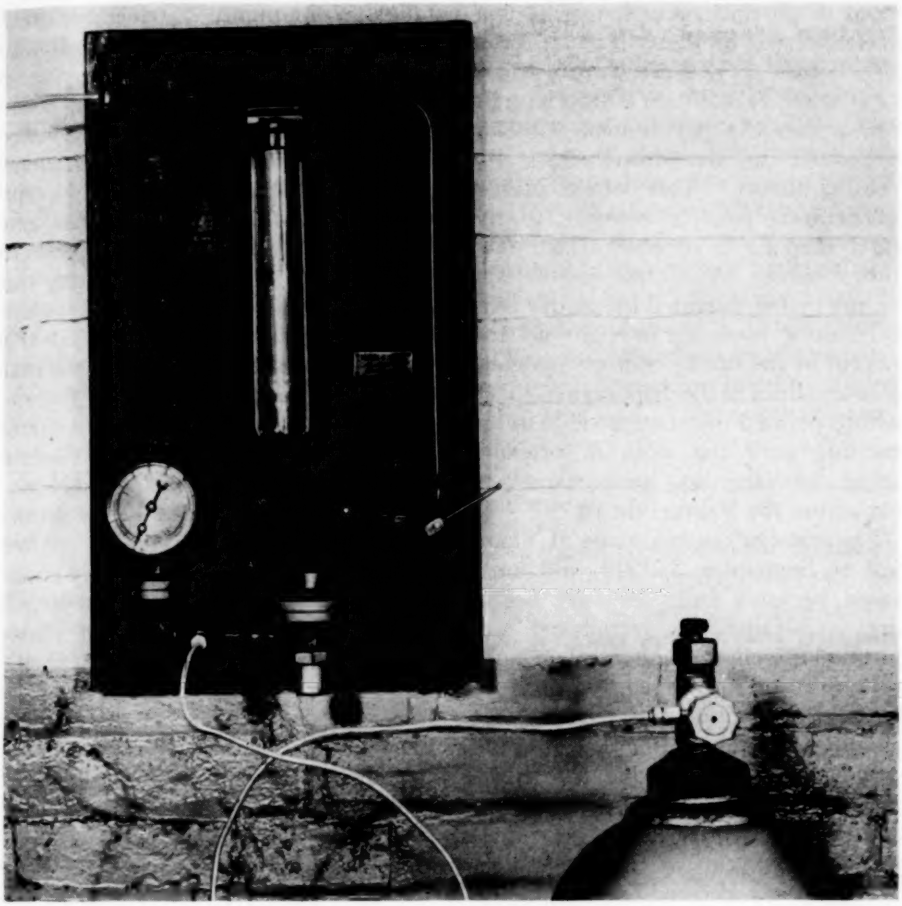

FIG. 1. Early Wallace & Tiernan Chlorinator

stream at Dover. This time we raised our price to $200. Fortunately for our finances, payment on the two installations was received fairly promptly.

James A. Newlands, whose name I mentioned above, was acting as consultant for the Stamford Water Works, which was considering a hypochlorite plant. Newlands wanted an automatic device to feed a sterilizing agent in proportion to the flow of water, which fluctuated widely and rapidly. Wallace and I discussed the matter and offered to install a Venturi-operated automatic chlorinator for $500 before we had even made the design. We guaranteed that the apparatus would operate satisfactorily for two years and would proportion the chlorine properly. We even went so far as to absolve the water company from any loss in case of patent infringement. Mind you, all for the sum of $500! This surely was a mark of our confidence and ignorance.

It was only a matter of a few days until Wallace had figured out a way of handling the problem. Three bal-

anced diaphragms, functioning as two, were operated by the differential pressure across a Venturi throat in the water main, to maintain a drop in pressure across the gas control valve in proportion to the drop across the Venturi throat. This would give a proportional flow of chlorine to the water through a variable orifice (the control valve). A simple, low-voltage d-c. toy motor, operated by six dry cells and costing some six or eight dollars, was cut in and out by contacts operated by connections to the diaphragms. This motor operated the control valve in the gas line until the drop in pressure across the valve was proportioned to that across the Venturi throat.

The installation was made at Stamford on September 3, 1913, and functioned perfectly from the very beginning. Chlorine was introduced into the intake well through a silver tube and a diffusor submerged to a depth of 25 ft. So sensitive and accurate was the automatic chlorinator that it would vary the flow of chlorine before the change in the flow of water was indicated by the Venturi meter.

Later that year we installed automatics at New Haven, Torrington and Hartford, Conn. The automatic feature of these three machines was modified to eliminate the electric motor.

In June 1913 Herman Rosentretter, of the Newark, N.J., Water Dept., hearing of our installations for Jersey City, gave us an order for a direct-feed manual-control machine for the entire Newark supply. The installation was made at the Macopin intake, using diffusors which fed into an open well.

In July 1913 we installed a direct-feed machine at the pumping station of the Bernardsville, N.J., Water Co. The apparatus fed directly into the intake line of a pump. I remember quite clearly going by train to Bernardsville, carrying the machine under my arm, then taking a bus to the south, down toward the pumping station, and walking at least two miles with the machine on my shoulder. Wallace and I spent the July 4 holiday cutting a tap into the suction line in the engine room. It was a pretty hot job. We hung the apparatus high up on the wall, above the hydraulic gradient, figuring that the water would not get back into the machine. Of course, as soon as the apparatus was turned off, when the pump was shut down, the chlorine in the line from the apparatus was quickly absorbed by the water, and before morning the machine was flooded. After the development of a satisfactory check valve, the installation was completed.

In October 1913 the city of Philadelphia called for bids on chlorine apparatus for five filter plants. We offered direct-feed machines, and the Electro Bleaching Gas Co. solution-feed machines. Although we were the lower bidders, the contract was awarded to Electro Bleaching Gas. This was our first experience in which the low bidder did not get the job. Naturally we were very much disappointed, but we accepted the situation, feeling that the city had a right to purchase whatever equipment it thought best for its needs.

The Boys' Club at Waterbury, Conn., wanted a machine to sterilize its swimming pool. After a direct-feed apparatus proved unsuccessful, we developed a solution-feed machine using an enclosed glass jar in which a volumetric meter was submerged and into which an impinging jet of water was introduced to effect the solution of the gas. The scheme worked out very well and we made quite a number of instal-

lations of that type. The maximum capacity was about 10 lb. of chlorine per day.

Trenton, N.J., was in the market for a solution-feed machine of a much greater capacity than ours, and we developed an enclosed glass-jar arrangement with an impinging jet which, for its size, had a very large dissolving capacity. Being a closed system, the danger of gas escaping was eliminated. This type was also very successful in operation.

My files show that in September 1914 we had 23 installations in eighteen different cities.

In July and August 1914 New York City ran comparative tests on the equipment of the manufacturers of chlorine apparatus, then three in number. We installed a direct-feed manual control, and the results of this test were very satisfactory to us.

On April 4, 1916, we installed nine of our direct-feed units to treat the water of the new and the old Croton, N.Y., aqueducts, with a capacity of 340 mgd. This installation functioned very well until the water became cold, when chlorine hydrate forming in the diffusors caused difficulty. Later on, this installation was changed to a solution-feed type.

By this time we were pretty thoroughly established in the chlorination field. In solving practical problems, we had found it necessary to make a great number of ingenious devices to meet special operating conditions. For the glass solution tower we had substitued the injector, to dissolve the chlorine. We had developed special valves for various purposes; cements; lubricating materials for valve packing; rubber tubing and hard rubber of formulas best suited to withstand corrosion; and machines of ever increasing capacity and constantly improved design. We had developed the vacuum type of apparatus for manual, semiautomatic and automatic control. The time and cost of all these things was simply tremendous, and only a genius like C. F. Wallace could have accomplished such results. As a matter of fact, after a nationwide poll on the occasion of the 150th anniversary of the founding of the U.S. Patent Office, Wallace was named as one of the nineteen great inventors in the United States and was given a suitable memento.

Conclusion

The use of chlorine in the sanitation field is not confined merely to the sterilization of water. Higher standards of water quality are requiring more and more accuracy and reliability of chlorine control equipment. A great expansion in the treatment of sewage has made necessary installations of very large capacity. Today the Detroit Sewage Disposal Plant has a capacity of some 54,000 lb. of chlorine per day. Compare this with the 10-lb. machine at Dover, N.J. It would be folly, however, to say that we have reached the top. Development and improvement in the means of application and treatment will go on. Means of treating water, actuated by the chlorine demand itself, have been perfected and a similar device for sewage is just around the corner. What the future will bring I would not venture to guess, but the constant thought, energy and genius of men engaged in this field are bound to produce further improvements and, probably, new and more satisfactory methods.

It has been a long journey from the simple capillary of Nesfield to the Detroit Sewage Disposal Plant. Teamwork has been necessary on the part of the chlorine producers, the apparatus inventors and manufacturers, the chemists and the engineers, in both private practice and public service.

And thus, the "Green Goddess," locked up from the dawn of time in the "Castle of Chemical Compounds," discovered by the wizardry of the research chemist, freed by the magic of the electrochemical engineer and physicist, controlled by the genius of the inventor, made available to the art of sanitation throughout the land by the vision of the executive and the persuasive activity of the sales engineer, now reigns as the great "Prophylactic Queen," a guardian and protector of the health of mankind.

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The Behavior of Chlorine as a Water Disinfectant

By Gordon M. Fair, J. Carrell Morris, Shih Lu Chang, Ira Weil and Robert P. Burden

A paper presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J., by Gordon M. Fair, Dean of Faculty of Eng., Grad. School of Eng., Harvard Univ., Cambridge, Mass.; J. Carrell Morris, Asst. Prof. of San. Chemistry, Grad. School of Eng., Harvard Univ., Cambridge, Mass.; Shih Lu Chang, Asst. Prof. of San. Biology, Grad. School of Eng. and School of Public Health, Harvard Univ., Cambridge, Mass.; and Ira Weil and Robert P. Burden, both of Grad. School of Eng., Harvard Univ., Cambridge, Mass.

DURING the 40 years of its use as a disinfectant for municipal water supplies in America, chlorine has proved itself to be so powerful and versatile that it and certain of its compounds are almost the sole chemicals employed for this purpose today. Yet, despite the accumulation of a large amount of practical knowledge about its use, science is only now beginning to unravel the fundamental chemistry and biology of its disinfecting action. It is the purpose of this paper to describe the recent advances which are leading to an understanding of the behavior of chlorine as a water disinfectant and to indicate briefly those large areas of its behavior that still remain to be explored.

Chemistry of Chlorine in Water

The destruction of bacteria and other micro-organisms by a substance such as chlorine is essentially the result of a chemical reaction between the active agent and some vital substance necessary to the functioning of the organism. The characteristic action of the agent is dependent upon its chemistry and can be interpreted only when that chemistry is known. This statement is especially true for chlorine because of the wide variety of chemical reactions in which it participates.

General Properties

The element chlorine is the second member of the seventh column of the periodic table. Surrounding its nucleus, it has an outer shell of seven electrons, and, since an outer shell of eight electrons has great stability, atoms of chlorine show a strong tendency to acquire an extra electron to complete a shell of eight. The tendency to acquire electrons manifests itself as oxidizing activity. Correspondingly, elemental chlorine is a powerful oxidizing agent and in the great majority of its chemical reactions acts as an oxidizer. Other properties of elemental chlorine are of importance in connection with its technical use as a disinfectant. Because it may be liquefied at room temperature, at pressures of 5 to 10 atmospheres, it is relatively easy to transport and store in necessary quantities. Because of its considerable solu-

bility in water—7,300 ppm. at 68° F. and 1 atmosphere—little difficulty is experienced in administering it to water in closely controlled amounts.

Hydrolysis

When chlorine is dissolved in water it undergoes a reaction of hydrolysis which may be represented by the chemical equation:

$$Cl_2 + H_2O \rightleftharpoons HOCl + H^+ + Cl^- \quad \ldots (1)$$

In strong solutions, only a portion of the chlorine reacts in this way, but at the concentrations ordinarily employed for water disinfection the hydrolysis is virtually complete. Only if the pH of the water is below 3, or if chlorine concentrations in the neighborhood of 1,000 ppm. or more are employed, is any measurable quantity of Cl_2 present. In addition, it has been shown (1) that the rate of the reaction is so rapid that the hydrolysis is essentially complete within a very few seconds at ordinary temperatures.

TABLE 1

Ionization Constants for HOCl

Temperature °C.	Temperature °F.	K / 10^{-8}
0	32	2.0
5	41	2.3
10	50	2.6
15	59	3.0
20	68	3.3
25	77	3.7

Actually, therefore, it is incorrect to speak of disinfection by chlorine, for chlorine itself is not present for more than a fleeting instant under conditions of practical disinfection. However, the oxidizing capacity of the chlorine is retained in the hydrolysis product, HOCl, and it is with this hypochlorous acid that the major disinfecting action of chlorine solutions is associated.

Ionization of HOCl

Hypochlorous acid undergoes a further reaction with water, one of ionization, which may be represented by the equation:

$$HOCl \rightleftharpoons H^+ + OCl^- \quad \ldots\ldots (2)$$

This is an essentially instantaneous, reversible process, so that one may write an equilibrium expression for it:

$$\frac{(H^+)(OCl^-)}{(HOCl)} = K \quad \ldots\ldots\ldots (3)$$

TABLE 2

Percentage of Free Chlorine as HOCl

pH	HOCl *per cent*	Free Chlorine per ppm. HOCl *ppm.*
4	100	1.000
5	99.7	1.003
6	96.8	1.033
7	75.2	1.33
8	23.3	4.3
9	2.9	34
10	0.30	331
11	0.030	3,300

In this expression the parentheses stand for activities (approximately equal to molar concentrations) of the enclosed substances, and K, called the ionization constant, depends only on the temperature. Values of K at various temperatures, compiled from a survey of experimental researches on the ionization of HOCl, are shown in Table 1.

Rearrangement of the ionization constant equation gives:

$$\frac{(OCl^-)}{(HOCl)} = \frac{K}{(H^+)} \quad \ldots\ldots (3a)$$

Hence the relative amounts of hypo-

chlorous acid and hypochlorite ion present in a solution of "free chlorine"* are a function of the hydrogen ion activity, or pH. Analyses for "free chlorine" always determine the sum of the two species. Table 2 shows the percentage of the free chlorine present as undissociated HOCl at various pH values at 20°C. The table also records the amount of free chlorine required to give 1 ppm. of HOCl.

Since, as will be shown, the HOCl is the principal disinfectant in chlorine solutions, the efficiency of these solutions is a function of pH and varies in much the same way as the percentage of HOCl.

Hypochlorites

Hypochlorites, such as chloride of lime, calcium hypochlorite and bleach solution, establish this same ionization equilibrium in water. For example, when calcium hypochlorite is dissolved in water, it ionizes according to the equation:

$$Ca(OCl)_2 \rightarrow Ca^{++} + 2\,OCl^- \ldots (4)$$

The hypochlorite ions then combine with hydrogen ions from the water, as shown by the reaction:

$$H^+ + OCl^- \rightleftharpoons HOCl \ldots\ldots (2a)$$

This is just the reverse of the previous ionization equation (Eq. 2). The same equilibrium expression and constant hold, and the relative amounts of hypochlorous acid and hypochlorite ion at a given pH are exactly the same as for a chlorine solution. Hence, at the same pH, chlorine solutions and hypochlorite solutions must have the same disinfecting efficiencies. Reported differences in efficiency should be attributed either to experimental error or to failure to carry out the tests at the same pH value. The addition of chlorine tends to lower the initial pH value, whereas the addition of hypochlorite tends to raise it.

Chloramines *

The disinfecting action of chlorine solutions is further modified by the reaction of the hypochlorous acid with certain substances of frequent occurrence in natural waters. Ammonia and many organic amines combine with hypochlorous acid to give the chloramines. Again, as in the ionization of the hypochlorous acid, the oxidizing capacity of the chlorine is retained by the chloramines, so that starch-iodide and standard *o*-tolidine tests record chlorine combined with nitrogen as well as "free chlorine." Since the molecular nature of the chlorine has been modified, however, the disinfecting power is also changed.

The most important of the reactions of chlorine with nitrogen compounds is that of hypochlorous acid with ammonia itself. Although it is known that three compounds, monochloramine (NH_2Cl), dichloramine ($NHCl_2$), and nitrogen trichloride (NCl_3), may be formed, very little has been reported about the fundamental character of these reactions or about the interrelationships among them. Investigations initiated in the Laboratories of Sanitary Engineering at Harvard † on the ammonia-hypochlorous acid reactions have so far led to these conclusions:

* See editorial note on p. 1061.

* See editorial note on p. 1061.

† The results quoted as issuing from these laboratories were obtained in researches supported in part by the Office of the Quartermaster General, in part by the Engineer Research and Development Laboratories and in part by the Wallace & Tiernan Research Fund in Chlorination.

1. The formation of the chloramines is a stepwise process for which the successive reactions

$$NH_3 + HOCl \rightarrow NH_2Cl + H_2O \quad (5)$$

$$NH_2Cl + HOCl \rightarrow NHCl_2 + H_2O \quad (6)$$

$$NHCl_2 + HOCl \rightarrow NCl_3 + H_2O \quad (7)$$

may be written.

2. The rate of the first step, the formation of monochloramine, is very much dependent on the pH of the solution. The maximum rate occurs at a pH of 8.3 and decreases rapidly at higher and lower pH values. For example, at 25°C., with 0.8 ppm. of chlorine and 0.32 ppm. of ammonia-nitrogen, it requires about one minute for the reaction of 99 per cent of the chlorine, whereas at pH 5 it requires approximately 210 minutes and at pH 11 approximately 50 minutes. The reaction has been shown to be bimolecular in accordance with the equation presented, and the variation in rate with pH can be calculated precisely on the basis of the solution equilibria that occur. The rate of the reaction also varies greatly with the temperature. Q_{10} values (*see* p. 1059) of 2.0–2.5, depending on the pH, have been obtained.

3. The general statement that dichloramine is formed predominantly at low pH values (5–6.5) and monochloramine at high pH values (greater than 7.5) can be interpreted in terms of the equilibrium reaction:

$$2\,NH_2Cl + H^+ \rightleftharpoons NH_4^+ + NHCl_2 \quad (8)$$

An excess of hydrogen ions should displace this reaction to the right, yielding greater amounts of dichloramine at lower pH values. This equation also predicts that the relative proportions of monochloramine and dichloramine should be affected not only by the pH, but also by the excess ammonia present. This has been confirmed by spectrophotometric measurements, which also give a value of 6.7×10^5 for the equilibrium constant, where:

$$K_{eq} = \frac{(NH_4^+)(NHCl_2)}{(H^+)(NH_2Cl)^2} \quad (9)$$

Table 3, calculated from this constant, shows the relative percentages of monochloramine and dichloramine at various pH values in solutions with a chlorine to ammonia-nitrogen weight ratio of 5:1.

Just as the disinfecting efficiency of solutions of free chlorine will vary with pH because of a change in the HOCl: OCl^- ratio, that of chloramine solutions will vary depending on the $NHCl_2$: NH_2Cl ratio. Consequently, any fundamental approach to the problem of disinfection by chlorine or its compounds must have as a background the types of basic chemical data that have been presented.

TABLE 3

Equilibrium Chloramine Distribution

pH	Chlorine as Dichloramine
	per cent
5	84
6	62
7	35
8	15
9	6

Chlorine Demand

Other reactions that lead to a loss of oxidizing chlorine also occur. Since HOCl is a strong oxidizing agent, its reaction with reducing substances is to be expected and results in the so-called "chlorine demand." In the reactions

included under this heading, the chlorine atom manifests its great tendency to gain electrons and is thereby changed into the chloride ion or organic chloride. In this form, the chlorine atom no longer has oxidizing properties or disinfecting power. The substances responsible for the reduction of chlorine include inorganic Fe^{++}, Mn^{++}, NO_2^-, and H_2S, along with the greater part of the organic material in the water. The reaction of the inorganic substances is generally rapid and stoichiometric; that of the organic material is generally slow, and its extent depends upon the excess concentration of available chlorine present. Since the amount of organic material in natural waters is usually closely related to the color or stain, the organic chlorine demand can often be approximately estimated from the depth of color.

The occurrence of these reactions is a disadvantage to the use of chlorine as a disinfectant, for one must provide sufficient chlorine to take care of these side reactions before a reliable disinfecting action can be assured. Yet the occurrence of these side reactions stems from the same basic property that makes chlorine such a potent disinfectant—its high oxidizing activity—and the bad must therefore be accepted with the good in order to secure the activity.

Break-Point Reaction

Ammonia or organic amines may also exert chlorine demand in the "break-point reaction." This is another phenomenon which, like the formation of chloramines, is of great importance in disinfection but of which virtually none of the fundamental chemistry is known. Even the products of the reactions are uncertain. The active chlorine is probably reduced to chloride and the stoichiometry of the process indicates that ammonia-nitrogen is oxidized to the + 1 valence state, corresponding to N_2O, but this may result from a combination of products, such as N_2 and NO_3^-, rather than from any single product.

Experiments now in progress have so far established several points:

1. The rate of the reaction is strongly dependent on pH. A maximum rate is obtained at about pH 7.5 and decreases rapidly at high and low pH values.
2. One of the substances concerned in the break-point reactions is probably dichloramine.
3. The rate of the reaction is only slightly dependent on the temperature.
4. The rate of the reaction is very dependent on the total concentration of dissolved salts.

The complexities of the break-point reactions are so great that considerable additional work must be done before a consistent theoretical treatment can be achieved.

Biological Reactions of Chlorine

The way in which the remarkable disinfecting power of chlorine solutions is achieved has been the subject of speculation ever since the time of the first use of chlorine as a disinfectant. But the research necessary to provide an experimental foundation for theories of the mechanism of the disinfecting process was begun only a few years ago.

Mechanism of Cell Destruction

Early ideas that the action of chlorine was due to nascent oxygen or to a complete oxidative destruction of the organisms soon had to be abandoned be-

cause of the small concentrations of hypochlorous acid required and because of the failure of other oxidizing agents to work similarly. It was apparent that there was some selective attack on a vital and highly sensitive portion of the cell, but no one knew what this might be. The researches of Green (2) and his coworkers at Columbia University have now provided a satisfactory solution. According to Green, the death of the organism results from

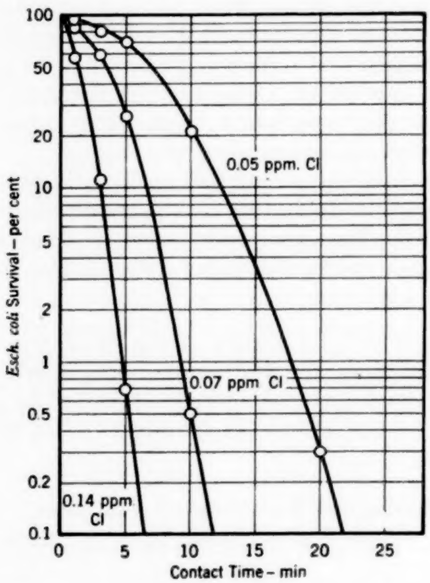

Fig. 1. Length of Survival of *Esch. coli*

a chemical reaction of HOCl with an enzyme system in the cell that is essential for the metabolic functioning of the organism. The enzyme probably attacked is triosephosphate dehydrogenase, which is found in practically all cells and is essential for the utilization of glucose. Attack on other enzymes is not excluded, but triosephosphate dehydrogenase was found to be especially sensitive to oxidizing chlorine. The reaction was presumed to take place with $-SH$ groups of the enzyme, which are oxidized by the chlorine. This theory provides an explanation of the extreme sensitivity of organisms to chlorine, since enzymes are present in cells in very minute quantities and yet are absolutely essential as catalysts for metabolic activity.

These ideas do not, however, furnish a complete answer to the problem of chlorine disinfection, for, when the

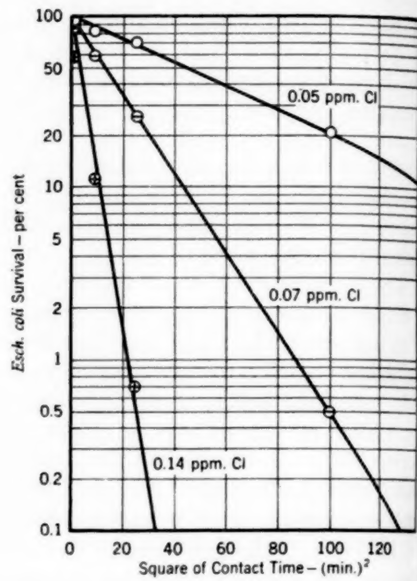

Fig. 2. Length of Survival of *Esch. coli*

enzymes are removed from the cell, they are equally susceptible to attack by many oxidizing agents, such as H_2O_2 and $KMnO_4$, whereas chlorine is markedly superior in its attack on intact cells. The difference can be explained on the basis that, for the intact cell, not only the ability of the reagent to react with the enzyme is of concern, but also its ability to gain access to the enzyme by penetrating through the cell wall. Laboratory

studies indicate that it is this latter factor—the rate of diffusion of the active agent through the cell wall—which largely determines the rate of disinfection and the relative efficiency of various disinfecting materials. From this point of view, it is not primarily the strong oxidizing power of HOCl that makes it a superior disinfectant, though that is essential, but rather its small molecular size and electrical neutrality. These allow it to pass readily through the cell membrane. Confirmation of this hypothesis must be sought in more extensive fundamental standing of the disinfection process. Up to the present, the only thorough studies of these factors as they relate to the action of chlorine solutions on bacteria have been made by Butterfield *et al.* (3) and by Wattie and Butterfield (4, 5). Even their admirable results, which form the basis for the following discussion, are not entirely satisfactory for theoretical calculations, however, and it is hoped that the extreme difficulty of the experiments that must be conducted will not prevent further studies of this type with theoretical objectives in mind.

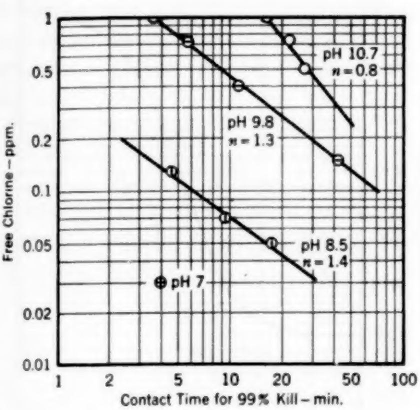

FIG. 3. Free Chlorine Requirements

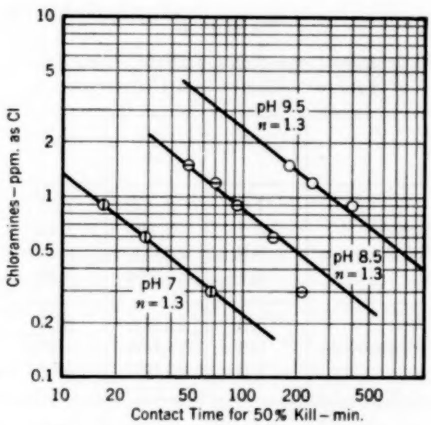

FIG. 4. Chloramine Requirements

studies of the rate of kill of organisms by various disinfecting agents and of variations in the rate with changing conditions.

Disinfection Efficiency

The principal factors that affect the efficiency of destruction of a particular species of organisms are: time of contact, concentration of organisms, concentration of disinfectant, temperature, and nature of the disinfectant. Dynamic studies of all these elements are essential for a thorough under-

Time of contact. The effect of contact time on the killing of organisms has generally been expressed in terms of Chick's Law, which may be written in the form:

$$\log \frac{N}{N_0} = -kt \ldots\ldots (10)$$

Here N/N_0 is the fraction of the original number of organisms remaining at time t, and k is a proportionality constant. A plot of $\log N/N_0$ against t for various times of contact should give

a straight line. Figure 1, prepared from the data of Butterfield *et al.* (3) for the destruction of *Esch. coli* by chlorine at pH 8.5 and 2°–5°C., shows that Chick's Law does not hold for disinfection by chlorine. Similar curves are obtained at other pH values, at other temperatures, for other species of bacteria * and for chloramines as well as free chlorine.

Linear relations are created for the results in Fig. 1 if log N/N_0 is plotted against t^2 rather than t. This is shown in Fig. 2. A relation of this character can be explained in two ways: (1) as a combination of slow diffusion through

TABLE 4

Temperature Dependence of Disinfecting Action of Aqueous Chlorine and Chloramines

	pH	*E* *cal.*	Q_{10}
Aqueous Chlorine	7.0	8,200	1.65
	8.5	6,400	1.42
	9.8	12,000	2.13
	10.7	15,000	2.50
Chloramines	7.0	12,000	2.08
	8.5	14,000	2.28
	9.5	20,000	3.35

the cell wall and a rate of killing dependent upon the concentration of disinfecting material inside the cell; (2) on the assumption that there are three to four active centers in the organism and that the organism is not dead until all of these centers have been destroyed (6). Further studies are needed to clarify these points.

Concentration of organisms. Virtually nothing is known about the effect of concentration of bacteria on the rate of disinfection. Butterfield (3) refers to one series of experiments with an initial concentration of organisms tenfold smaller than that normally employed and states that no significant difference in the percentage destroyed at various times was observed. This is the result one would intuitively expect, but it should be checked more extensively.

Concentration of disinfectant. Changes in disinfection efficiency with

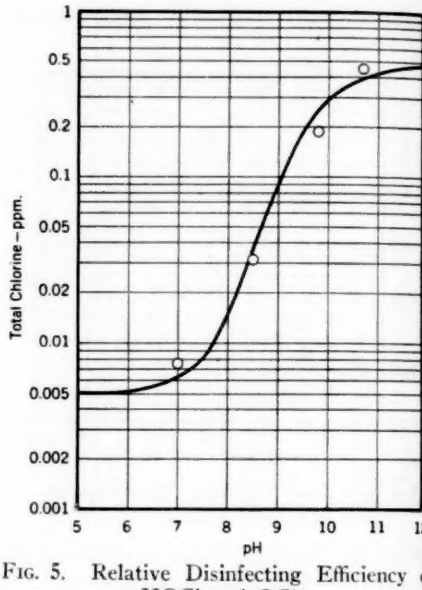

FIG. 5. Relative Disinfecting Efficiency of HOCl and OCl⁻

concentration of the disinfectant can be expressed mathematically by the equation:

$$C^n t = k \quad \quad (11)$$

In this equation, C represents the concentration of disinfectant, t represents the time required for a constant percentage of the organisms to be destroyed and n is a constant which may be called the concentration exponent. High values of n indicate that the dis-

* There are some exceptions to the general failure to obey Chick's Law. For example, destruction of *Shigella dysenteriae* by chloramines below pH 8 follows the law quite closely. Exploration of the reasons for this might yield information of considerable value.

infectant decreases rapidly in effectiveness as it is diluted; with low values of n, the time of contact becomes more important than the dosage.

Values of n are determined by plotting log C against log t and measuring the slope of the lines. A series of such plots, using the times required for 99 per cent of the bacteria to be killed, is shown in Fig. 3 for free chlorine solutions. A similar series for chloramines appears in Fig. 4, except that the times are for 50 per cent kills of the bacteria, sufficient data for 99 per cent kills not being available. No theoretical significance can be attached to the values of n obtained; the equation itself is without theoretical foundation and is just an expression for the correlation of data.

Temperature of disinfection. If either the rate of diffusion through the cell wall or the rate of reaction with an enzyme determines the rate of disinfection, its variation with temperature is best expressed by the equation:

$$\log \frac{t_1}{t_2} = \frac{E(T_2 - T_1)}{4.575 T_1 T_2} \quad \ldots\ldots (12)$$

The symbols T_2 and T_1 stand for two temperatures (in degrees Kelvin) between which the rates are being compared; t_1 and t_2 are the times required for equal percentages of kill at a fixed concentration of disinfectant; and E, called the activation energy, is a constant characteristic of the reaction. When $T_2 - T_1 = 10$, the ratio t_1/t_2 is frequently called Q_{10}. For studies in the vicinity of 20°C., Q_{10} is approximately related to E by the formula:

$$\log Q_{10} = \frac{E}{39{,}000} \quad \ldots\ldots (13)$$

Values of E and Q_{10} for the destruction of *Esch. coli* by chlorine and chloramines, computed from the work of Butterfield *et al.* (3), appear in Table 4.

Nature of disinfectant. Figure 3 shows that the disinfection efficiency of chlorine decreases markedly with an increase in pH. This can be accounted for by postulating that HOCl is a far stronger disinfectant than OCl^-, since the percentage of the free chlorine in the solution in the form of HOCl decreases very rapidly with increasing pH, as shown previously. By assuming an additive disinfecting efficiency for HOCl and OCl^-, one can calculate a theoretical curve for the total amount of free chlorine required to produce a given percentage of kill in a specified time at various pH values. The equation employed is:

$$R = A \frac{1 + \frac{K}{(H^+)}}{1 + B\frac{K}{(H^+)}} \quad \ldots\ldots (14)$$

in which R is the required total chlorine, A is the concentration of HOCl alone required to produce the desired percentage of kill and B is the ratio of the efficiency of OCl^- ion to that of HOCl. In Fig. 5, the observed concentrations of aqueous chlorine required to kill 99 per cent of *Esch. coli* in 30 minutes at 2°–5°C. have been plotted against the pH and fitted with a theoretical curve whose equation, corresponding to Eq. 14, is:

$$R = 0.005 \frac{1 + \frac{2.2 \times 10^{-8}}{(H^+)}}{1 + \frac{0.012 \times 2.2 \times 10^{-8}}{(H^+)}}$$

The value of B used, 0.012, indicates that the OCl^- ion possesses about 1/80 of the disinfecting efficiency of HOCl under the stated conditions.

Since Fig. 5 shows that at pH 7 and 8.5 essentially the whole disinfecting action is due to HOCl, whereas at pH 10.7 it is chiefly due to OCl^-, the char-

acteristic constants obtained at these pH values may be identified with the disinfecting process for the corresponding species. Thus the values $n = 1.4$ and $E = 7{,}000$ calories are connected with disinfection by HOCl, while the values $n = 0.8$ and $E = 15{,}000$ cal. refer to the reaction of OCl^-. It is of interest to note that the value of $E = 7{,}000$ for the action of HOCl is in the range of activation energies for diffusion, whereas the value of $E = 15{,}000$ for the action of OCl^- is more characteristic of a chemical reaction. Perhaps, therefore, the rate-determining processes are different for these two substances.

A plot similar to that in Fig. 5 might be made for the chloramines, but the data are so scanty, and reliable values for the chloramine equilibria are so recent, that this has not yet been done. However, the manner in which the disinfecting efficiency of chloramine solutions decreases with increasing pH (*see* Fig. 4) indicates qualitatively that NH_2Cl, which is favored at the high pH values, is a less efficient disinfectant than $NHCl_2$. In addition, a tentative quantitative evaluation of the rate of change with pH suggests that the entire disinfecting action in the solutions studied may have been due to $NHCl_2$ and that NH_2Cl may be so weak a disinfectant that its influence was not felt.

Effects on Other Organisms

The biological reactions of chlorine have been illustrated in this paper for but a single organism, *Esch. coli,* a "type organism of water contamination" rather than a water-borne pathogen. The pathogenic organisms that should be considered in connection with water chlorination include: (1) the enteric vegetative bacteria (*Eberthella, Shigella, Salmonella* and *Vibrio* species); (2) intestinal protozoa, the most important representative of which is *Entameba histolytica;* (3) worms, such as the blood flukes (*Schistosoma* species); and (4) viruses—for example, the virus of infectious hepatitis.

Each of these groups of organisms differs in its reaction to chlorine, and there is considerable variation, too, in the behavior of the different species within the individual groups. There is some evidence, furthermore, that the comparative reaction of different organisms to one form of chlorine is not necessarily maintained relative to other forms.

Much research will have to be done before the pattern of the biological reactions of significant organisms is fully established. Of the four groups of pathogenic organisms, the enteric bacteria are most easily destroyed by ordinary chlorination procedures, whereas the cysts of *E. histolytica* appear to be the most resistant (7).

Conclusion

A remarkable record of accomplishment has been established by chlorination during the 40 years since it was first applied to a public water supply in America. Pride in the reduction of water-borne typhoid fever and dysentery, however, must not obscure the need for intensifying researches into the chemistry and biology of water chlorination. The cost of water disinfection, to be sure, is negligible in terms of the savings that it has effected and will continue to effect in the prevention of sickness, suffering and death. The total annual expenditure for chlorine as a water disinfectant and its significance in the prevention of water-borne disease are sufficiently large, however, to warrant the cost of all the

investigations that must yet be entered upon to acquire the necessary understanding of this—surely the most important—water works chemical. No industry can long afford the luxury of ignorance, even though it is tempered by accomplishment; neither can a profession that, like the water works profession, is so clearly devoted to the protection and promotion of the public health.

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Editor's Note

The A.W.W.A. committee which has prepared the chapter on "Chlorination and Other Disinfection Practices" for the forthcoming Manual of Water Quality and Treatment *has set up the terms "free available chlorine residual" and "combined available chlorine residual" to replace the terms "free chlorine" and "chloramine," respectively. The committee considers that free available chlorine may exist as elemental chlorine, hypochlorous acid ($HOCl$) or hypochlorite ion (OCl^-)—or as hypochlorous acid and either of the other two forms—depending on the pH of the solution. The concept of combined available chlorine envisages the presence of ammonia or other nitrogenous compounds which have the capacity to combine with chlorine (or hypochlorous acid) and thus modify its rate of bactericidal action.*

Based on the foregoing distinction, the committee has suggested that chlorination practices be classified as free residual chlorination and combined residual chlorination.

Mechanization of Public Utility Billing and Accounting

By A. Knaff

A paper presented on May 5, 1948, at the Annual Conference, Atlantic City, N.J., by A. Knaff, Supervisor, Public Utility Div., Burroughs Adding Machine Co., Detroit, Mich.

THE progress in the mechanization of public utility billing and accounting during the last thirty years is so closely related to the developments in office machinery that the historical treatment of one necessitates consideration of the other.

About sixty years ago William S. Burroughs, himself an accountant, invented and built the first practical adding machine for commercial use. He visualized a maximum sale of 8,000 machines, after which the company could liquidate. To date more than 2,000,000 machines have been built by the Burroughs Adding Machine Co., and the mechanization of office work is far from being complete.

From 1890 to 1910 the use of adding machines was greatly expanded and a few courageous souls even conceived the idea of posting ledgers by machine. This period saw the beginning of some of the present-day accounting and statistical machines. The development and more widespread use of accounting machines at that time was, however, somewhat retarded by the almost universal suspicion of the loose-leaf ledger as a safe repository for accounting records. It remained for World War I and a shortage of accountants to compel a more general acceptance of machine records. Given the opportunity to prove its indispensability, machine accounting rapidly forged ahead.

During World War I, public utilities had to find ways of reducing the clerical time required to handle customer billing and accounting, and presented the problem to manufacturers of adding and accounting machines. The only accounting machines then available were of the type used for posting accounts receivable and bank ledgers and statements. It was from these models that the first utility billing and ledger-posting machines were developed.

The first billing machines of the adding-machine type were designed to post only meter readings and consumption on the bills, the amounts being entered with rubber stamps or by pen and ink. Ledger accounts were posted by a separate operation, either with machines or manually. Typewriter accounting machines were also developed about that time for simultaneously writing the bills and posting the ledger by the use of carbon paper.

Although these machines offered relief, particularly in the large metropolitan areas, the clerical situation was so acute that radical measures had to be taken. One of these was the elimination of the customers' ledger and the

substitution of a copy of the bill (now commonly referred to as a stub or office record). This saved the time of entering the bills in the ledger, as well as the time of entering the meter orders, and brought about the era of so-called bookless bookkeeping, which subsequently became known as the "stub plan" of customer accounting.

Shortly after the development of the stub plan, another method, called the "register sheet plan," made its appearance. This was also based on eliminating the customers' ledger. It provided for registering 20 to 40 bills on one sheet and was considered a less radical departure from orthodox accounting procedure than the stub plan. In fact, it was patterned somewhat after the Boston type of ledger then in common use in utilities. In succeeding years, however, the register sheet plan did not approach the stub plan in popularity, probably because it lacked the flexibility of a unit record.

With the advent of bookless bookkeeping plans, billing became the most important part of customers' accounting and brought on rapid developments in billing machines to meet the new requirements. These developments, particularly in the adding-machine type of billing machine, made possible the complete writing of the bills and stubs in one operation. This step, along with the cycling of meter reading and centralization of billing, helped further to relieve the clerical problems of utilities which adopted bookless bookkeeping. Although bookless bookkeeping appealed to a large number of utilities, an equally large number preferred the customers' ledger, which brought about improvements in billing machines permitting the simultaneous writing of bills and ledgers.

The development of billing machines has been a continuous process. The first Burroughs model, a duplex machine, had a front-feed carriage and a repeat-print mechanism which made possible the writing of bills with stubs and the posting of the ledger—all in original print—in one continuous operation and produced a transcript of the bills as a by-product. Its successor, the multiple-register machine, was developed in 1926 and has been followed by such major advances as line proof of readings and consumption, the automatic bill ejector, an increased number of registers, the multiple-print mechanism and many others. Today the billing machine is a highly specialized product designed to write bills, post ledgers and supply statistical data as well, with greater speed and accuracy and with less operator effort than was dreamed of when the first machines were put into use.

Concurrently with the development in billing machines many innovations in customers' accounting practices were devised so that customers' billing and accounting is now considered to be one of the outstanding streamlined operations in the accounting field. The basic principle of streamlining is predicated on handling a uniform volume of work each day and eliminating duplication of effort as far as possible. It may not be amiss to discuss streamlined operations briefly.

Meter Reading Practices

Probably the first and most important step in streamlining affects meter reading. Meter reading routes are arranged geographically so that they can be covered by traveling the shortest distance. Schedules are prepared in advance and provide for a uniform number of meters to be read daily

throughout the month or quarterly period. The schedule also provides for a uniform number of days between reading periods. Meters are read in even numbers, which simplifies computation and decreases the size of the rate charts. Meter readers compute the consumption on entering the readings in the meter book, which permits the verification of the reading when the consumption appears abnormal. The reason for abnormal consumption can often be determined by the meter reader with a resultant reduction in investigation orders and customer complaints.

It is now common practice to estimate meter readings based on previous consumption when it is not possible to gain access to the meter. This saves the time of covering the route twice to pick up missed readings. The fact that the reading is estimated is indicated on the customer's bill with an appropriate explanation. Most utilities do not estimate the reading for two months in succession. When the reading cannot be secured the second month by the regular meter reader, arrangements are made with the customer by telephone or letter to obtain an actual reading.

Prior to billing, the meter books are reviewed for high and low consumption and other irregularities. Investigation orders are prepared and amounts of consumption which extend beyond the range of the rate charts are computed and checked. This reviewing operation guards against perpetuating irregularities, reduces customers' complaints and simplifies the billing work.

Customer Accounting

The customer accounts and addressing plates are usually maintained in the same geographical order as the meter reading sheets. Each account is assigned a folio number which appears on the meter sheet, addressing plate, ledger account and customer index files. Most utilities maintain two such files, one of which is kept alphabetically and the other in house-number order by streets.

After the reviewing operation, the meter book and the corresponding bills and ledger accounts (when the ledger plan is used) are assembled at the billing machine for convenient handling by the operator. Rate charts are also placed in a convenient position for quick reference.

Modern billing machines are designed to write the bills and post the ledger accounts in one operation. As a by-product of billing, the machine produces a transcript of the bills and provides totals of the number of customers, the consumption and the amount by rate or revenue classes. The machine also checks the meter reader's computation of consumption.

There are many variations of bill forms in use, depending on the class of service rendered and the amount of information which it is desired to show on the bills. In recent years the use of postcard bills has greatly increased because of the savings in delivery expense.

Following the billing operations the bills are proved for accuracy by one of several methods. A fast, simple and accurate proving method—the "post list proof plan"—is to figure the bills a second time. An operator equipped with a rate chart and an adding machine goes through the meter book and lists the amounts corresponding to the consumption. The total thus obtained is reconciled with the billing-machine total. Differences

are easily located by comparing the proof list with the billing transcript, both being in the same order. This proves that the bills have been calculated correctly and that no accounts have been overlooked.

The totals obtained from the billing machines are used for journalizing the revenue and for setting up controls over groups of accounts. Controls may be established by meter books, or a group of meter books may be carried in one control.

As payments are made during the day, the amounts are validated on the customer's receipt. These amounts add into a locked total, which is balanced against the amount of cash in the drawer at the end of the day. This provides protection to the utility, the customer and the cashier.

The cash coupons are sorted by controls and then into account sequence. They are next posted to the accounts and the totals of the postings are proved with the day's total of payments and entered on the controls.

Just prior to the following month's billing period each control is balanced with the amounts remaining unpaid on the customer accounts. This method is commonly referred to as cycle balancing and is designed to eliminate end-of-month balancing peaks.

It will readily be seen that streamlined customer billing and accounting will permit a uniform flow of work throughout the month, with a resultant reduction in the idle time which would exist if personnel had to be provided to handle periodic or end-of-month peaks.

The era of expansion following World War I developed the need for up-to-date statistics on operating costs, inventories and plant construction costs to assist management in planning for the future. More recently, with the advent of social security and withholding taxes, unemployment insurance, and reports to federal and local governmental bodies, the statistical burden has increased still more. These requirements have brought about changes in handling the major divisions of general accounting, such as material and supplies; labor, including payrolls, paychecks and employees' earnings records; equipment accounting; accounts payable; summarizing distribution media; and posting to operating, work order, subsidiary and general ledgers.

The development of machines for handling general accounting has kept pace with the development of billing machines. Although machines have been successfully applied to all the major divisions of this work in many utility companies and municipal utility departments, they have not been accepted as widely as in customer billing and accounting. The general accounting field, therefore, offers great possibilities for mechanization and a resultant reduction in accounting expense.

Considerable progress has also been made by manufacturers of auxiliary equipment and office supplies, such as forms, ledger trays, binders, filing equipment, addressing machines, sorting and reproducing devices, summarizing boards and the like, which have greatly contributed to the successful application of machines to the billing and accounting work and have helped to lighten the burden of processing masses of figures.

Future Developments

Past developments in machines and offices practices appear to be a good criterion of what can be expected in the future.

World War II, with its extremely heavy demand on the manufacturing and public service facilities of the country, demonstrated the need for adequate production control. Many a manufacturer vividly remembers the headaches of procuring materials and scheduling the processing of parts so that they could be assembled into the end-product with the least possible delay. The need for adequate inventory control and accurate, up-to-date cost figures will also be recalled.

There is every reason to believe that the necessity for accounting and calculating machines will continue to increase. The cost of labor is high and all studies indicate that office costs will continue to rise for some time. Likewise, it should not be forgotten that office personnel is now rated hourly, and there is a greater need to think in terms of production obtained for this hourly rate. The 40-hour week and overtime pay have emphasized the value of eliminating peaks and finishing today's job today. The time has passed when business can afford to employ a pair of hands and permit them to function purely on a manual basis. Management must place tools in those hands which will increase their productivity. In order to do this, the office must be further mechanized. The elements of time and cost are too great to approach this problem in any other way.

To meet this situation, laboratory research is being carried on in several fields—notably color, powder metallurgy, plastics, electronics and the wider use of light metals. In addition, research projects have been established under Burroughs sponsorship outside its own laboratories for studies in scientific fields having a possible application to business-machine design. Particular emphasis is being placed on the further development of electronic circuits for high-speed calculations. Investigations have already shown that definite possibilities exist for utilizing electronics in the general processing of figures, especially on distribution jobs. Developments in this new electronic field may not come tomorrow or next year, but it is likely that commercial applications will be developed in the near future.

A Statistical Analysis of Water Works Data for 1945

By G. J. Schroepfer, A. S. Johnson, H. F. Seidel and M. B. Al-Hakim

A paper presented on Sept. 1, 1948, at the Minnesota Section Meeting, Winnipeg, Man., by G. J. Schroepfer, Prof. of San. Eng., Univ. of Minnesota; A. S. Johnson and H. F. Seidel, Instructors in Civ. Eng., Univ. of Minnesota; and M. B. Al-Hakim, Graduate Student of San. Eng., Univ. of Minnesota, Minneapolis, Minn.

THE "Survey of Operating Data for Water Works in 1945," published as an A.W.W.A. report (1), included a mass of information on production, consumption, physical characteristics and financial conditions pertaining to a number of American water works systems. It has occurred to the authors that the very bulk of the published survey would preclude the drawing of conclusions from it without detailed analysis. Because of the diversity, amount and usefulness of the results of such an analysis, a study was undertaken to determine the usual values, trend, spread and possible interrelation of these data. It is hoped that the results of this analysis will be of benefit to water works men in a number of ways. Every superintendent and operator likes to know how his system compares with the usual national values, and with cities having characteristics similar to his own. The possible value of this type of information in public relations work is suggested. To engineers engaged in some of the many phases of the water industry, the statistical data should also be of interest.

The original information was obtained through a questionnaire sent by the Association to 975 water properties, of whom 462 replied. These returns did not always provide all of the information requested; furthermore, the number of values in some classifications was insufficient to permit a complete statistical analysis. As stated in the A.W.W.A. report, there are certain limitations on the accuracy and completeness of the data. In this paper, the data are analyzed as presented without any attempt at interpretation or elimination.

The cities represented included those having a population of 10,000 up to 6,775,000 (one community with a population of approximately 1,000 has not been considered in this analysis). It should be pointed out that the total number of communities in the United States within this range of population was 1,077 in 1940. Almost all of the larger communities (over 100,000 population) are included.

Scope of Study

This analysis is divided into three parts: (1) production and sales, (2) physical data and (3) financial data. In each of these parts several items are included. In the first section, produc-

tion is studied by population groups, by geographical location and in terms of rates; sales are analyzed by population groups and per cent of production sold; and finally a study of private supplies by population groups and regions is included. In the second section, the physical data of the system, such as the number of miles of main and the distribution of hydrants and valves, are analyzed. The third section, on financial data, covers book value, operation and maintenance cost, and revenue per capita in relation to population, production and source of supply. Rates are analyzed by population, production and amount of water used. Also included is a financial comparison of public and private supplies.

In the analysis of the various data, it was necessary to employ population groups. United States Census Bureau groupings were used, except that all communities with a population of over 500,000 were considered as one groups and per cent of production sold; group because of the small number of cities involved. The Census Bureau groups, as modified in this paper, are:

Group	Population
1	10,000– 25,000
2	25,000– 50,000
3	50,000–100,000
4	100,000–250,000
5	250,000–500,000
6	over 500,000

It would be well to point out here that the data on production and sales were sometimes given as fairly rough approximations and that the great majority of the population estimates were reported in round numbers only. The same is true of some of the other items in the survey. As a consequence, the analysis can be no more accurate than the basic data used and should be interpreted in that light.

TABLE 1

Production, by Population Groups

Pop. Group	No. of Cases	Per Capita Production—*gpd.*						
		Min.	Max.	Mean	1st Q.†	Median	3rd Q.‡	Mode
1	148	33.5	366.7	123	77	106	144	85
2	96	43.7	546.4	128	83	109	141	85
3	66	43.0	394.4	119	81	99	145	85
4	45	66.6	333.8	126	98	113	132	110
5	21	63.2	172.2	117	96	115	140	100
6	22	89.5	244.5	145	120	145	166	160
U.S.*	398	33.5	546.4	125	85	110	145	100

* Includes Groups 1–6.
† First Quartile.
‡ Third Quartile.

Statistical Procedure

Various statistical procedures were employed in the analysis of the data. Most of these were eliminated in the preparation of the final version of this paper because of the amount and type of data and the use to which the analysis might be put. This study is therefore reduced to the preparation of frequency curves and the calculation of the mode, mean, median and quartiles

when the data are sufficient for such determinations. For the benefit of the reader unfamiliar with statistical terminology, a brief statement of the significance of some common terms is presented.

Frequency curve. A frequency curve is usually obtained by arranging the numerical data according to size. To draw such a curve, ranges or class intervals are used which are plotted on a horizontal axis (abscissa), while the number of cases occurring in each class is plotted vertically (ordinate).

Another type of frequency curve can be obtained when the percentage of cases above (or below) a certain value is plotted as the abscissa, and the magnitude of the item under consideration is plotted as the ordinate. The curve obtained is called a distribution curve. Illustrative examples of both frequency (Fig. 1) and distribution curves (Fig. 2) are presented. These curves show how frequently a certain value occurs in the study concerned, thus their name of frequency or distribution curve.

Mean. The mean represents the arithmetic mean or average of all the values concerned. It is the most widely known and used statistical device, especially because of the ease of computation. By definition it is obtained by dividing the sum of all the data by the number of items concerned.

Median. The median is the value of the middle item when the items are arranged according to size. It is thus an average of position, and its value is such that 50 per cent of the values in a mass of data under consideration are greater and 50 per cent are smaller than the median value. It can be calculated by grouping the data according to size and then determining the middle item. When a large mass of data is to be analyzed, as in this paper, the median can be calculated mathematically. For this purpose, however, it should be remembered that the median value

TABLE 2

Production, by Public and Private Supplies

Pop. Group	Public			Private		
	No. of Cases	Mean	Median	No. of Cases	Mean	Median
		gpd. per capita			*gpd. per capita*	
1	141	123	106	7	122	105
2	90	128	108	6	133	115
3	58	120	100	8	112	97
4	38	130	115	7	105	103
5	16	120	120	5	107	97
6	21	145	148	1	135	135

Ownership	No. of Cases	Per Capita Production—*gpd.*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
Public	364	33.5	546.4	126	84	111	145	100
Private	34	57.6	265.7	117	92	103	135	98

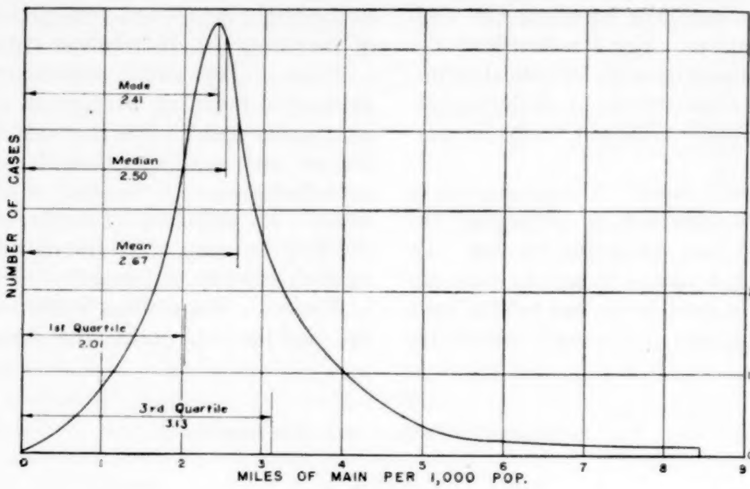

FIG. 1. Frequency Curve

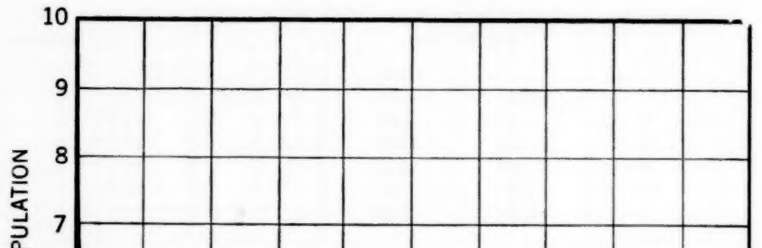

FIG. 2. Distribution Curve

represents the mid-point of the distribution curve.

The advantage of using the median value is that it is easily calculated and is not distorted in value by unusual items. It is more typical than the mean of the series of data considered because of its independence of unusual values. On account of its greater significance in many problems, the median should find more frequent use in the water works field than it does at present.

Quartiles. Just as the median divides the distribution into two parts, the quartiles divide the distribution into four parts. The second quartile is the median itself. Referring again to the distribution curve (Fig. 2), the interquartile range (between the first and the third quartiles) includes the middle 50 per cent of the data. Quartiles can be calculated in the same way as the median values and can be considered as lower and higher usual values.

Mode. The mode is the most frequent or most common value, provided that a sufficiently large number of items is available to give a smooth distribution. When ideally smooth frequency curves are obtained, the mode represents the maximum or most frequent value on them. The mode is also an average of position and is the most usual or typical value, and thus the most descriptive average. However, the mode can only be approximate and, as previously stated, it is significant only when a large number of data is available.

The results of the study are reported in tables and diagrams. The type of diagram that appeared to be the best illustration for this kind of study is a modified version of the common bar graph, which is well suited to showing ranges, means, medians and first and last quartiles. General mean and median values for the whole group of data are also shown on these diagrams.

TABLE 3

Production, by Geographic Regions

Region	No. of Cases	Per Capita Production—*gpd.*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
New England	44	42.2	182.7	94	70	90	114	75
Mid-Atlantic	76	52.0	394.4	143	94	122	170	105
South	68	43.0	153.9	95	75	91	115	80
N. East Central	86	33.5	267.1	113	85	108	135	105
N. West Central	68	51.7	308.0	110	81	99	133	94
Mountain	17	108.2	301.5	202	171	188	258	177
Pacific Coast	39	73.4	546.4	194	124	173	241	175
Entire U.S.	398	33.5	546.4	125	85	110	145	100

The foregoing explanatory description of statistical terminology has been included to promote a more general understanding of the data which are to follow, and thereby to increase its usefulness.

Production and Sales

The items analyzed in this section on production and sales of water include: (1) production, gallons per day

per capita (Survey Table 2, Column 10)*; (2) sales, gallons per day per capita (Survey Table 2, Column 11); modal value was 100 gpd. per capita. The variations in production due to the size of the city, private ownership of

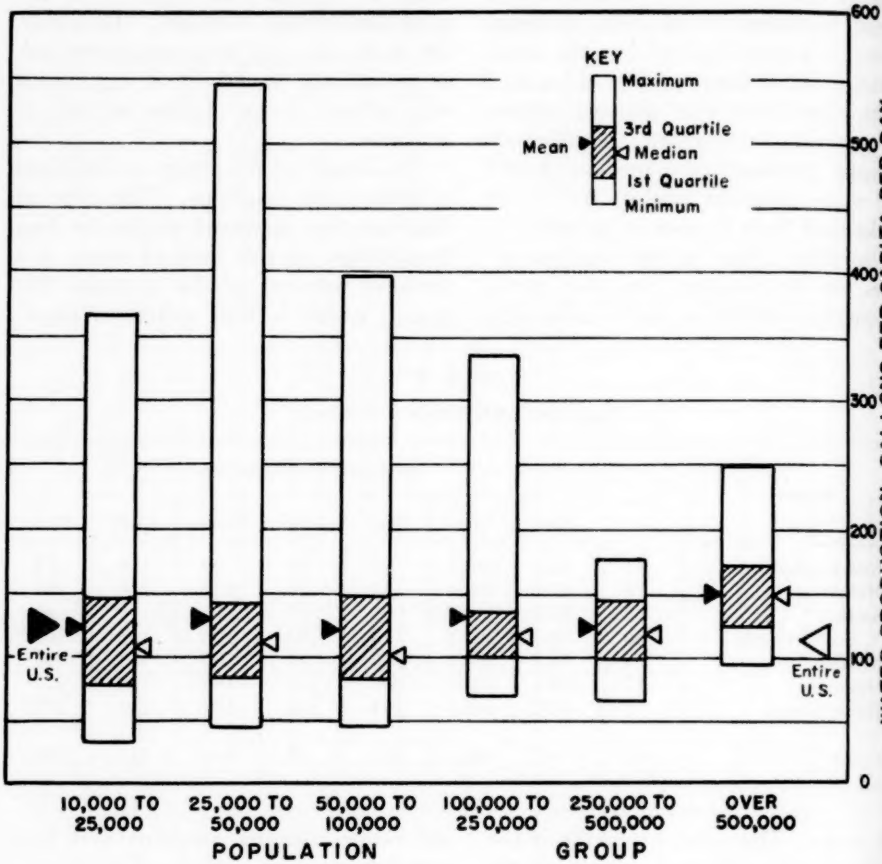

Fig. 3. Production, by Population Groups

and (3) percentage of production sold (Survey Table 2, Column 9).

Production

As recorded in Survey Table 2, Column 10, the annual water production in the 398 cities reporting ranged from 33.5 to 546.4 gpd. per capita. The mean production for all cities was 125, the median value was 110 and the

the utility, and location are considered below.

Size of city. When the data were analyzed by groups according to size of city (Survey Table 1, column 3), no consistent trend was noticeable, as indicated in Fig. 3. Mean and median values for the first five population groups (10,000 to 500,000) show little variation; only for cities of over 500,000 population are these values somewhat higher than normal. As shown

* References to "survey tables" indicate tables in the A.W.W.A. report (1).

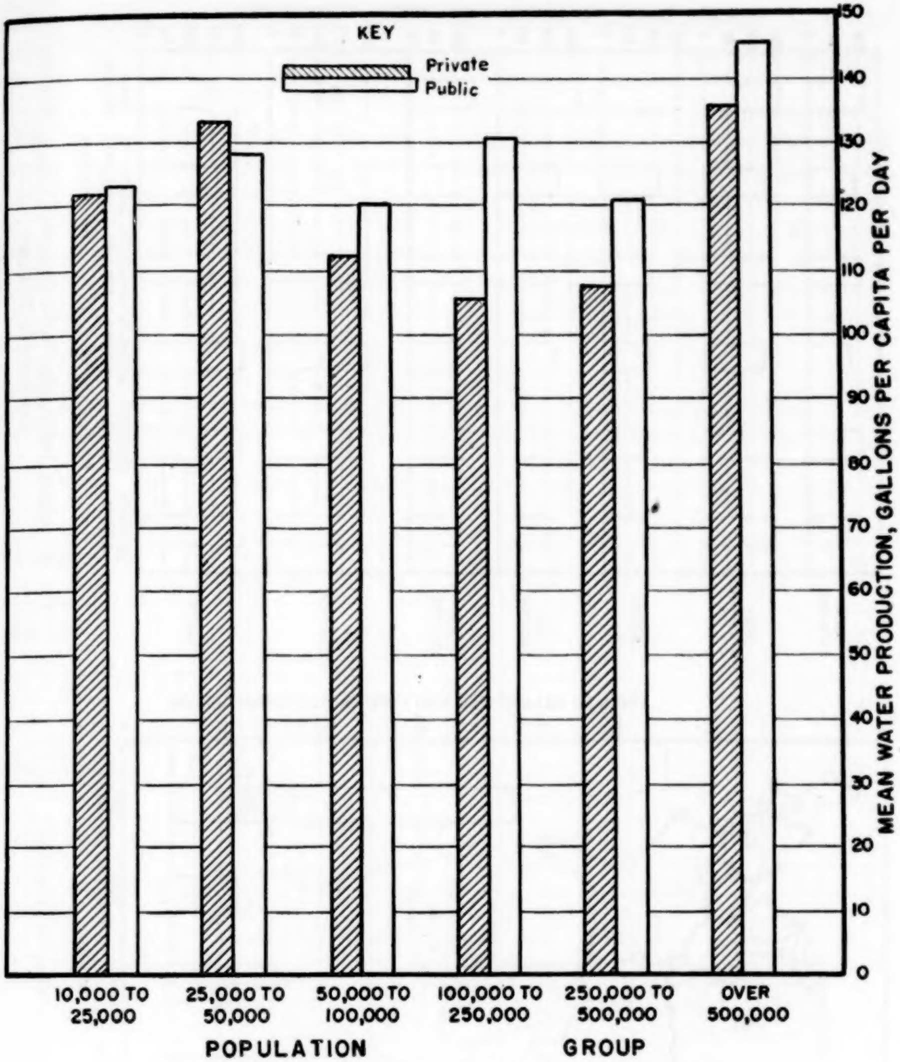

FIG. 4. Mean Production, by Public and Private Supplies

in Fig. 3, the interquartile range is usually found to be much nearer the minimum value than the maximum. This indicates that the occurrences of unusually high production are rather few in number. Somewhat more complete results of the study of production by population groups than can be presented in graphical form are given in Table 1.

Ownership of supply. Information on the control or ownership of the supply (Survey Table 1, Column 4) is analyzed next. Of the 42 cities replying to the questionnaire which are served by privately owned water supplies, per capita production values were available for 34. Production by private supplies varied from 57.6 to 265.7 gpd. per capita—a smaller range than that for

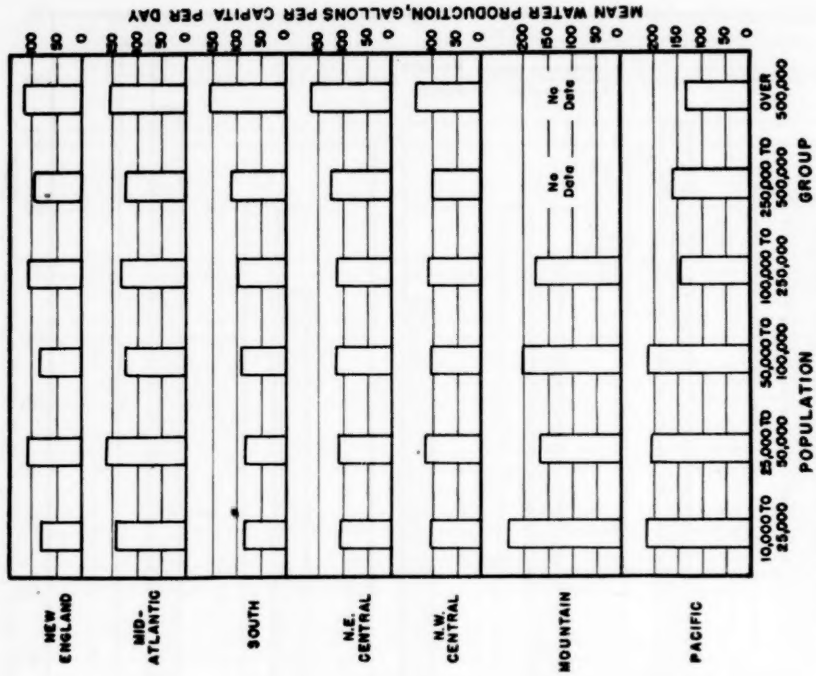

FIG. 6. Mean Production, by Population Groups Within Geographic Regions

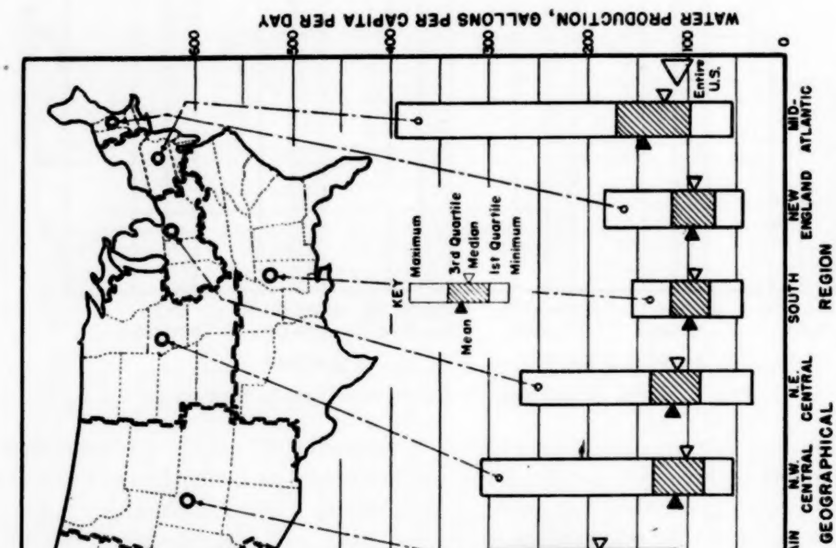

FIG. 5. Production, by Geographic Regions

publicly owned supplies. The mean production was 117, the median value was 103 and the modal value was 98 gpd. per capita.

The privately owned supplies reporting are located across the entire country but are most common in the East and on the Pacific Coast. For example, of the 42 reporting, 8 private supplies were located in Pennsylvania, 5 in Connecticut and 5 in California. and publicly owned supplies, by population groups, is presented in Table 2.

Geographical location. One of the most interesting and rewarding studies made was an analysis of the per capita water production in different sections of the country. It was impractical to make a study of this type for each state because many were represented by a half dozen cities or less; instead,

TABLE 4

Mean Per Capita Production, by Population Groups Within Geographic Regions

Region	Item	Population Group						
		1	2	3	4	5	6	1–6
New England	Cases	19	10	7	5	2	1	44
	Mean, *gpd.*	83	109	85	111	98	118	94
Mid-Atlantic	Cases	31	13	11	10	3	8	76
	Mean, *gpd.*	145	163	124	133	125	155	143
South	Cases	16	18	15	10	8	1	68
	Mean, *gpd.*	87	85	94	101	112	155	95
N. East Central	Cases	32	24	15	8	3	4	86
	Mean, *gpd.*	106	111	117	111	125	167	113
N. West Central	Cases	32	16	10	3	3	4	68
	Mean, *gpd.*	105	118	107	112	102	135	110
Mountain	Cases	7	6	3	1	0	0	17
	Mean, *gpd.*	233	168	205	175			202
Pacific Coast	Cases	11	10	5	8	2	3	39
	Mean, *gpd.*	215	205	212	146	160	132	194

When analyzed by population groups, the data indicate that the mean per capita production by private supplies is less than that by publicly owned supplies, with the exception of the 25,000 to 50,000 population group (*see* Fig. 4). It will also be noted that the mean per capita production is not lowest for small cities but rather for those of intermediate size. A complete comparison of production for both privately seven geographical regions were defined and the data from all the cities within a region were analyzed as a group. The regional groupings adopted are those commonly used for studying or describing many other types of data:

1. *New England*—Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut

2. *Mid-Atlantic*—New York, Pennsylvania, New Jersey, Maryland, Delaware, District of Columbia
3. *North East Central*—West Virginia, Ohio, Michigan, Indiana, Illinois
4. *North West Central*—Wisconsin, Minnesota, Iowa, Missouri, Kansas, Nebraska, South Dakota, North Dakota
5. *South*—Virginia, North Carolina, South Carolina, Kentucky, Tennessee, Georgia, Florida, Alabama, Mississippi, Louisiana, Arkansas, Oklahoma, Texas
6. *Mountain*—Montana, Idaho, Wyoming, Colorado, Utah, Nevada, Arizona, New Mexico
7. *Pacific Coast*—Washington, Oregon, California, Hawaii.

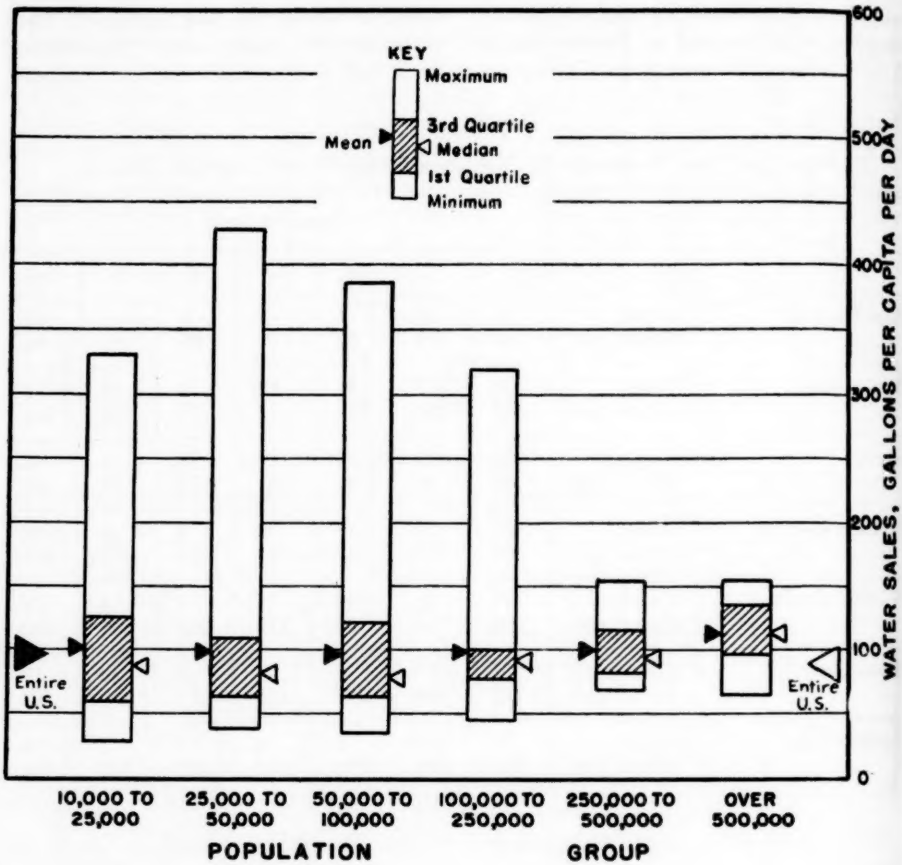

Fig. 7. Sales, by Population Groups

Although West Virginia is ordinarily considered a Mid-Atlantic state, it is included in this study with the North East Central group because of the character and location of all West Virginia cities which replied to the questionnaire. Washington, D.C., is considered to be in the Mid-Atlantic re-

gion, and Honolulu, T.H., is included with Pacific Coast cities.

The differences in the production of water in various regions, as shown in Fig. 5, were striking. The mean production was highest (202 gpd. per capita) in the Mountain region. The mean production in the Pacific states was almost as high (194 gpd.) and, interestingly, the range between minimum and maximum values in this area was the greatest for any region. Mean and median production for the Mountain and Pacific Coast regions was approximately 60 per cent higher than the same values for the entire country. By contrast, per capita production in the South and in New England was roughly 20 per cent lower than for the country as a whole. Complete results of the study of production by geographical regions are presented in Table 3.

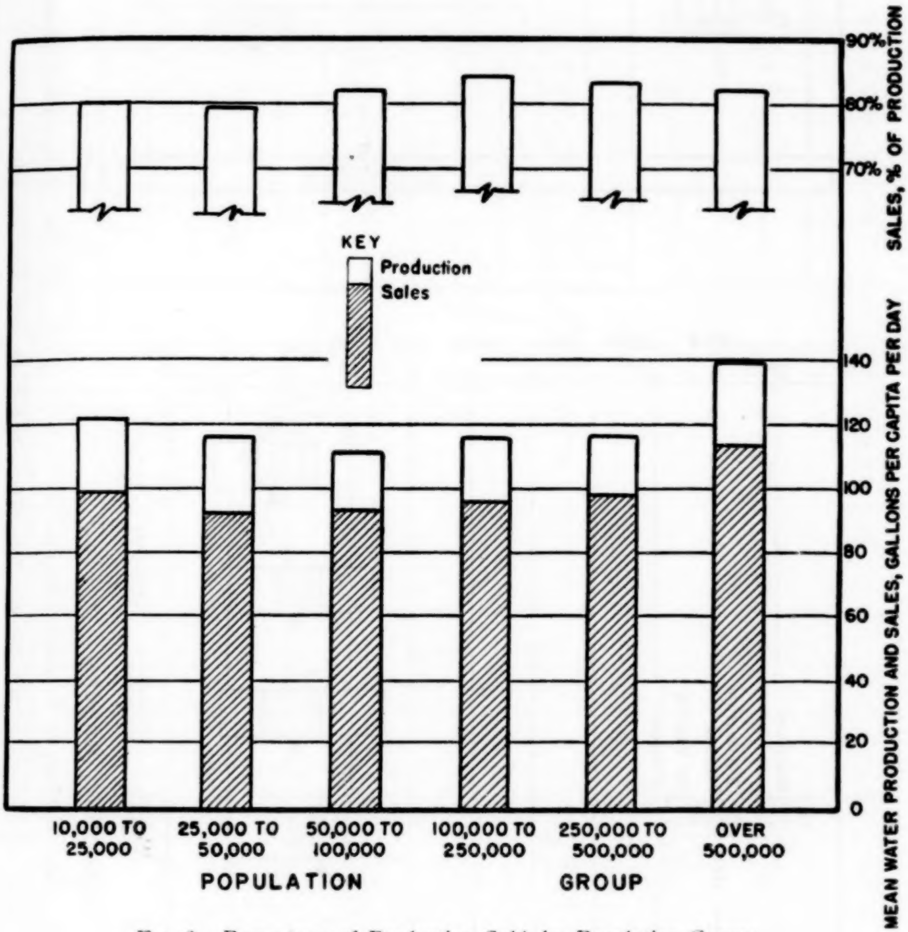

Fig. 8. Percentage of Production Sold, by Population Groups

As a method of further analysis of the data by geographical location, the

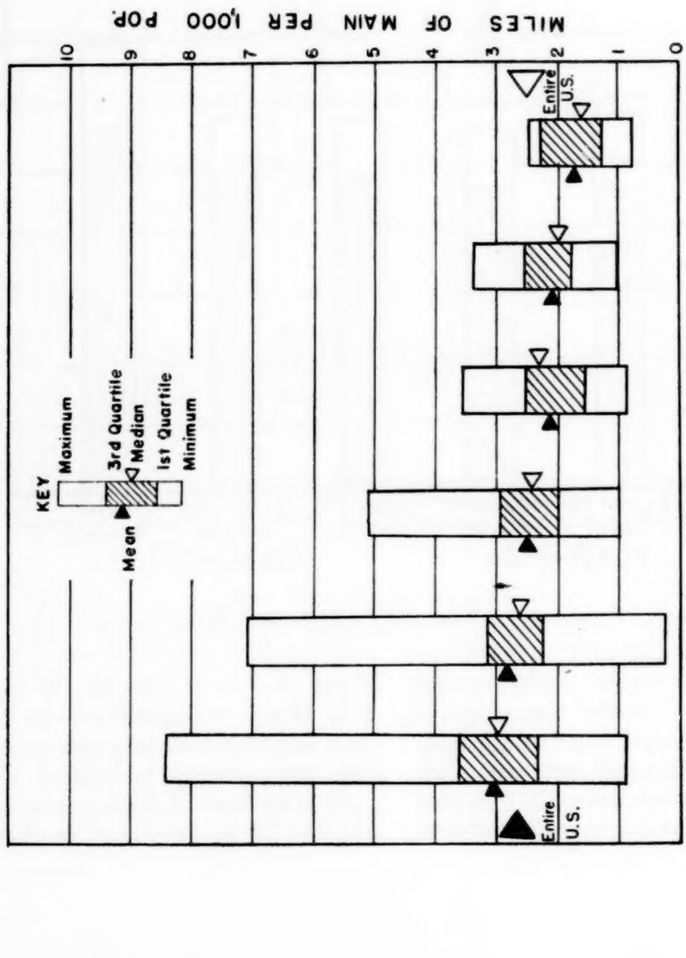

FIG. 9. Miles of Main, by Population Groups

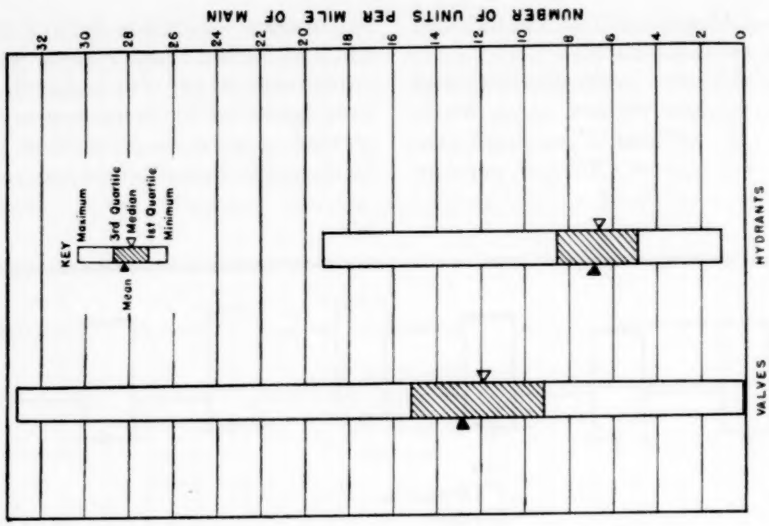

FIG. 10. Valves and Hydrants per Mile of Main

TABLE 5

Sales, by Population Groups

Pop. Group	No. of Cases	Per Capita Sales—*gpd.*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	120	28.1	333.3	102	59	88	126	55
2	88	37.2	430.0	96	63	82	109	64
3	60	34.2	389.0	95	62	79	122	65
4	40	45.4	320.0	97	78	91	100	94
5	19	68.6	154.0	99	82	93	116	91
6	17	65.6	156.0	114	96	113	136	106
U.S.	344	28.1	430.0	99	65	89	116	75

TABLE 6

Production Sold, by Population Groups

Pop. Group	No. of Cases	Production Sold—*per cent*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	113	40.03	98.73	80	73	81	90	85
2	82	31.77	98.97	79	72	82	89	82
3	57	60.40	98.55	82	78	83	89	83
4	39	52.71	99.99	85	80	87	91	88
5	19	65.00	97.04	83	80	84	88	83
6	17	48.16	99.99	82	80	84	92	85
U.S.	327	31.77	99.99	81	75	83	90	83

TABLE 7

Miles of Main by Population Groups

Pop. Group	No. of Cases	Miles of Main per 1,000 Pop.						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	156	0.83	8.36	3.01	2.31	2.94	3.55	3.10
2	106	0.22	7.07	2.82	2.24	2.56	3.14	2.35
3	68	1.00	5.11	2.52	2.00	2.46	2.93	2.36
4	45	0.86	3.54	2.18	1.58	2.26	2.59	2.31
5	22	1.00	3.33	2.04	1.74	1.96	2.50	1.80
6	21	0.74	2.44	1.69	1.26	1.57	2.24	1.40
U.S.	418	0.22	8.36	2.67	2.01	2.50	3.13	2.41

mean production values for the cities within each region were broken down by population groups. The results of this work are plotted in Fig. 6 as a family of bar graphs and are also presented in Table 4. In some regions, trends were apparent which were in contrast to the slight and inconsistent variations

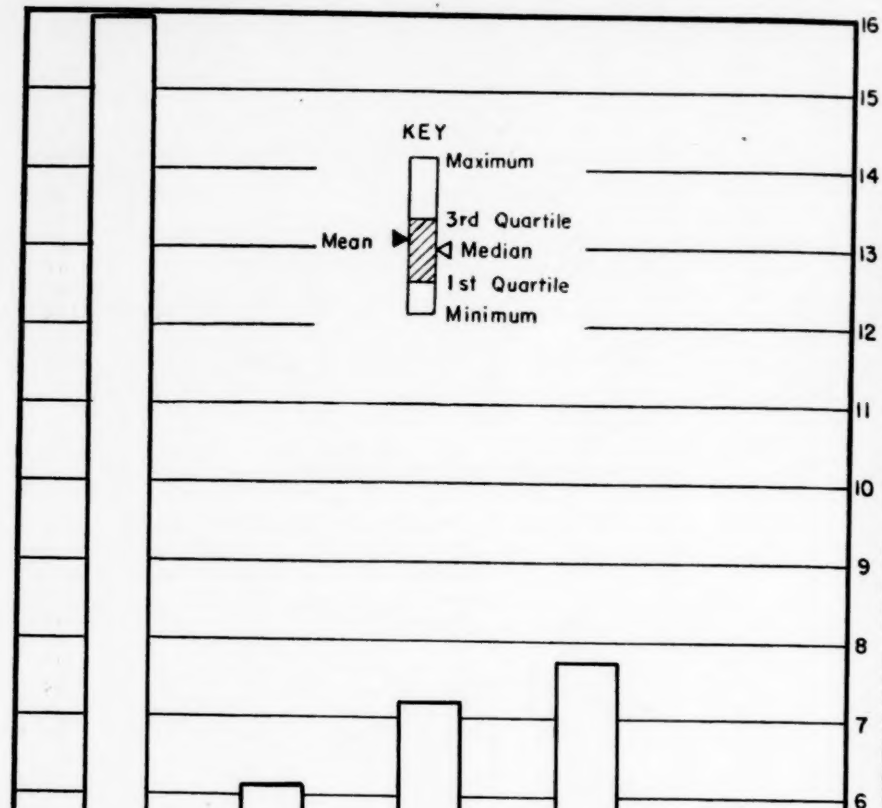

FIG. 11. Operation and Maintenance Costs, by Sources of Supply

in production with increase in size of city for the country as a whole. Production in the Mountain region dropped somewhat with an increase in size of city; production in the Pacific Coast region decreased very sharply in the larger cities. In the North East Central states and in the South, there was a consistent and considerable increase in production with increased population. Trends in the remaining three regions were similar to the trend, or lack of it, for the country as a whole.

Sales

To accompany the data on production, information on sales was also obtained and was recorded in Survey Table 2, Column 11. For the 344 cities reporting, sales ranged from 28.1 to 430.0 gpd. per capita. The mean sales value was 99, the median was 89 and the modal value was 75 gpd. per capita. As for production, the variations in sales due to size of city and private ownership were analyzed. Since the relationship between production and sales is fairly consistent, it was thought that a study of sales as affected by geographical location would be largely repetitious.

Size of city. When analyzed by population groups, the data on sales presented a slightly more consistent trend (Fig. 7) than did the data on production. Compared with the mean value of sales for all cities (99 gpd. per capita), the mean value for the first population group (10,000 to 25,000) was 102 gpd.; the mean value was progressively lower in each of the next two groups, then rose to a peak of 114 gpd. for cities of over 500,000 population. Complete results of the study of sales by population groups are presented in Table 5.

Ownership of supply. Of the 42 privately owned supplies, per capita sales values were reported for 28. Sales ranged from 47.1 to 430.0 gpd. per capita. The mean sales value was 103, the median value was 90 and the modal value was 96 gpd. per capita. It will be noted that these values are slightly higher than corresponding values for all supplies, public and private. When it is recalled that production in private supplies was lower than in public supplies, the data indicate in a general way that privately owned supplies produce less water but sell more of what they do produce.

TABLE 8

Hydrants and Valves per Mile of Main

	No. of Cases	Number per Mile						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
Hydrants	437	1.00	19.21	6.75	4.82	6.55	8.44	4.34
Valves	345	0.14	33.33	13.08	9.31	12.09	15.41	11.43

Percentage of Production Sold

Since approximately one-sixth of the cities reporting on production made no estimate of sales, and a smaller number of those giving sales data made no report of production, it was necessary to eliminate all such values from a study of the percentage of production sold. After this was done, complete

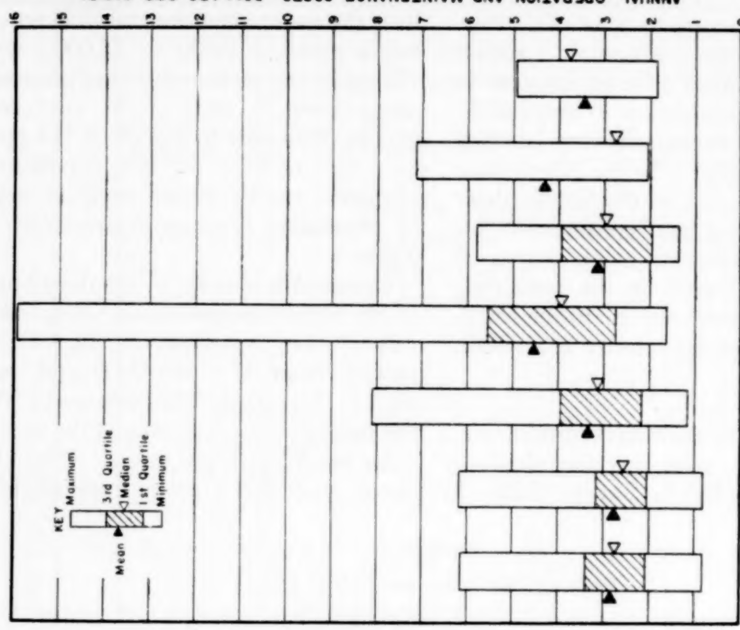

Fig. 13. Operation and Maintenance Costs, by Production Groups

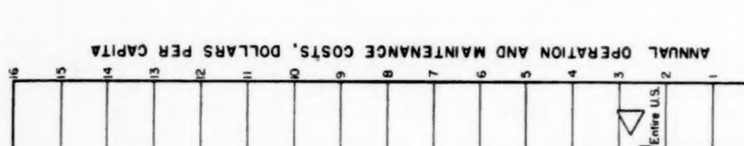

Fig. 12. Operation and Maintenance Costs, by Population Groups

data (both production and sales) were available for 327 cities.

Sales ranged from 31.77 to 99.99 per cent of production. The mean value was 81 and the median and modal values were both 83 per cent. More than one-fifth of the values fell between the limits of 80 and 85 per cent, and only one-seventh fell below 70 per cent. As was done for sales, the effect of size of city or private ownership on the percentage sold was studied.

Size of city. Percentage sold values were analyzed first by population groups. Figure 8 shows the results of this study in two ways. The bar graph in the lower portion of the chart is made up of mean values of production and sales for the 327 cities reporting both. The bar graph indicates the relative quantity of each and also the remarkable similarity of the trends for production and sales where both were given. The upper portion of the chart shows the mean percentage sold value for each population group and the small variation among them. Although production and sales are lower in the intermediate population groups, the percentage of production sold in these groups is higher than for all cities considered together. Complete results of the study of percentage sold, by population groups, are presented in Table 6.

TABLE 9

Number of Cases in Source-of-Supply Groups

Source of Supply	Cases Reported	
	Number	*per cent*
Wells	135	30
Streams	99	22
Impounding Reservoirs	80	18
Lakes	69	16
Springs	5	1
Combinations	58	13
Total	446	100

Ownership of supply. Of the 42 privately owned supplies, percentage sold values were available for 32. Among these, the percentage sold varied from 62.47 to 97.25 per cent, a much smaller range than for publicly owned supplies. The mean value was 84, the median value was 83 and the modal value was 91 per cent. As indicated previously, privately owned supplies apparently sell a somewhat higher percentage of their production than do those publicly owned.

Physical Characteristics

In this section on the physical characteristics of the systems the data analyzed include: (1) miles of main per 1,000 population (Survey Table 2, Column 13) and (2) valves and hydrants per mile of main (Survey Table 2, Columns 16 and 18).

Miles of Main

The number of miles of main per 1,000 population is studied first as a whole and then on a population group basis. Considering all the data, 418 communities are analyzed. Values range from 0.22 to 8.34 miles of main per 1,000 population. Mean, median and mode are, respectively, 2.77, 2.50 and 2.41. On a population basis, the results are as shown in Table 7 and Fig. 9.

It is interesting to note the regular decrease of the mean and median values with the increase in the size of the community. For example, in communities having a population between 10,000 and 25,000 the mean and median values are respectively 3.01 and 2.94 miles per 1,000 population. These values decrease regularly until they reach 1.69 and 1.57, respectively, for mean

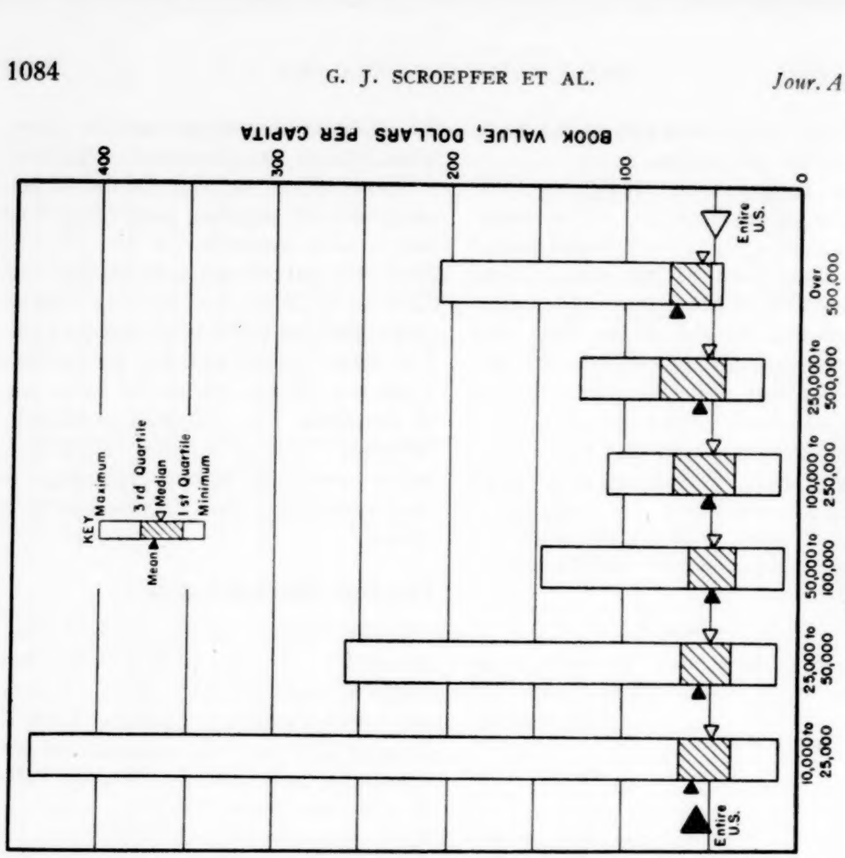

Fig. 15. Book Value, by Population Groups

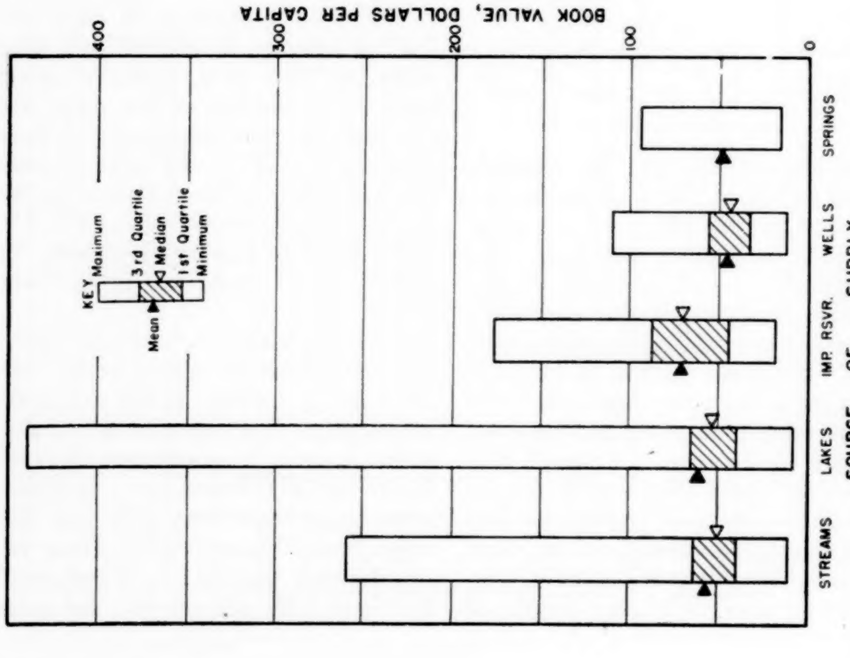

Fig. 14. Book Value, by Sources of Supply

and median in cities of over 500,000 population.

Valves and Hydrants

The other physical data of the system analyzed are the number of hydrants and valves per mile of main. For hydrants, 437 cities are analyzed and for valves, 345 cities. The results are shown in Table 8 and Fig. 10.

Financial Data

The items of financial data analyzed in this section include: (1) operation and maintenance costs per capita (Survey Table 1, Column 12), (2) book value per capita (Survey Table 1, Column 8), (3) revenue per capita (Survey Table 1, Column 10) and (4) monthly rates (Survey Table 2, Columns 2–5).

Each of these four items is studied by population groups. In addition, operation and maintenance costs, book value and revenue are analyzed for five different sources of supply. In the survey, 446 cities listed one or more sources of supply (Survey Table 1, Column 5), including streams, lakes, impounding reservoirs, wells and springs. No attempt was made to analyze the groups listing combined sources of supply because too few cases of any one type of combination occurred. Cities listing both streams and impounding reservoirs were grouped under impounding reservoirs. The number of cities using each of the five sources is shown in Table 9.

Operation and maintenance costs and book value are compared with production in addition to population and source of supply. The monthly charge for water used at the rate of 10,000 cu.ft. per month is compared with production and the charges for the four rates of use listed in the survey are analyzed by population groups.

The operation and maintenance costs, book value, revenue, monthly rate for the first 10,000 cu.ft. of water used, and the taxes paid, expressed as a percentage of revenue (Survey Table 2, Column 6), are analyzed for the privately owned water supplies listed in the survey.

TABLE 10

Operation and Maintenance Costs, by Sources of Supply

Source	No. of Cases	Per Capita Costs—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
Streams	91	1.15	15.91	3.25	2.35	2.98	3.64	2.99
Lake	63	1.28	6.06	3.05	2.04	2.90	3.75	1.92
Imp. Rsvr.	72	0.82	7.12	2.86	1.98	2.55	3.44	2.43
Wells	124	1.16	7.66	2.96	2.10	2.65	3.60	2.26
Springs	5	0.81	4.27	2.19		1.45		

Operation and Maintenance Costs

The annual costs of operation and maintenance in 417 communities are analyzed. The mean value of this item for the cities studied is \$3.02. The median and modal values are \$2.73 and \$2.35, respectively. The over-all range is \$0.81 to \$15.91 and the quartile range is \$2.11 to \$3.66. Factors other than source of supply, production and population which have an effect on

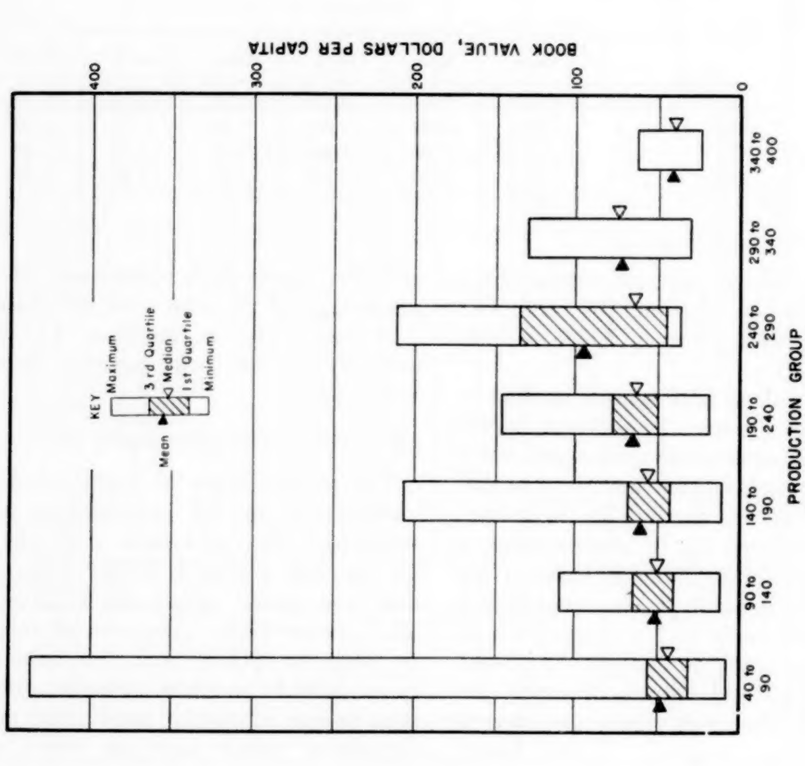

FIG. 16. Book Value, by Production Groups

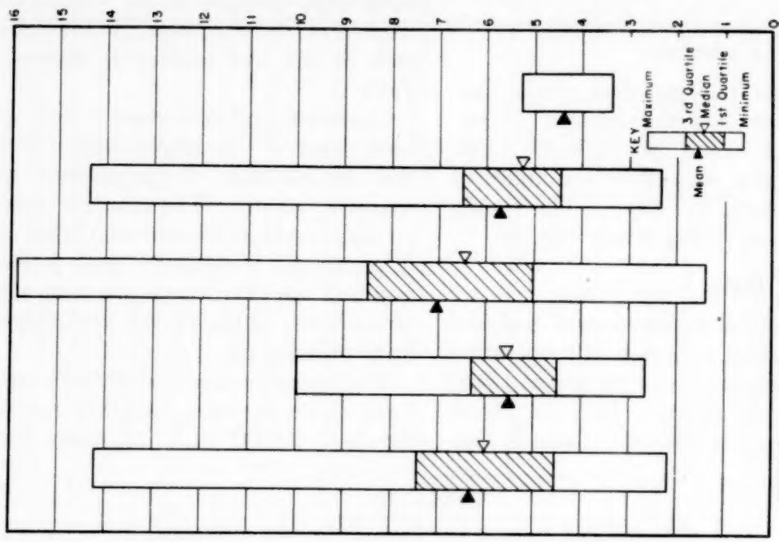

FIG. 17. Revenue, by Sources of Supply

TABLE 11

Operation and Maintenance Costs, by Population Groups

Pop. Group	No. of Cases	Per Capita Costs—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	155	0.81	15.91	3.44	2.33	3.10	4.10	2.75
2	106	1.28	7.12	3.09	2.28	2.93	3.64	3.12
3	69	1.07	6.06	2.75	1.92	2.52	3.24	2.45
4	45	1.11	5.57	2.45	1.81	2.29	2.84	1.90
5	20	1.16	4.09	2.37	1.78	2.20	2.57	
6	22	0.82	3.60	2.28	1.58	2.42	2.87	
U.S.	417	0.81	15.91	3.02	2.11	2.73	3.66	2.35

operation and maintenance costs—such as the type of purification, efficiency of administration and pumping requirements—unfortunately are not available for a further analysis of these costs.

Source of supply. Of the 446 cities which listed a source of supply, 33 did not report operation and maintenance costs per capita. This number, plus the 58 cities using a combination of sources, reduces to 355 the total number of cities capable of analysis. Based on mean and median values, cities using surface supplies (streams and lakes) have higher operation and maintenance costs than do cities using ground water. Of the four most common sources of supply, however, impounding reservoirs have the lowest operation and maintenance costs. Cities using streams as a source of supply have the highest operation and maintenance costs, followed by those using lakes, wells and impounding reservoirs, in that order. The group of cities listing springs as a source of supply has too few cases to permit any statistical analysis other than the computation of mean and median values. The statistical data are shown in Table 10 and Fig. 11.

Population groups. In this tabulation 417 cities are listed. Of the cities in the survey, 33 listed no operation and maintenance costs per capita. The statistical data are shown in Table 11 and Fig. 12.

TABLE 12

Operation and Maintenance Costs, by Production Groups

Per Capita Production *gpd.*	No. of Cases	Per Capita Costs—$					
		Min.	Max.	Mean	1st Q.	Median	3rd Q.
30– 80	79	0.81	6.14	2.81	2.08	2.72	3.40
80–130	179	0.82	6.16	2.76	2.05	2.55	3.17
130–180	76	1.13	8.08	3.31	2.18	3.12	3.95
180–230	22	1.62	15.91	4.52	2.75	3.95	5.55
230–280	16	1.35	5.80	3.14	1.95	2.95	3.95
280–330	5	2.03	7.12	4.30		2.75	
330–400	6	1.84	4.92	3.42		3.75	
530–580	1			3.44			

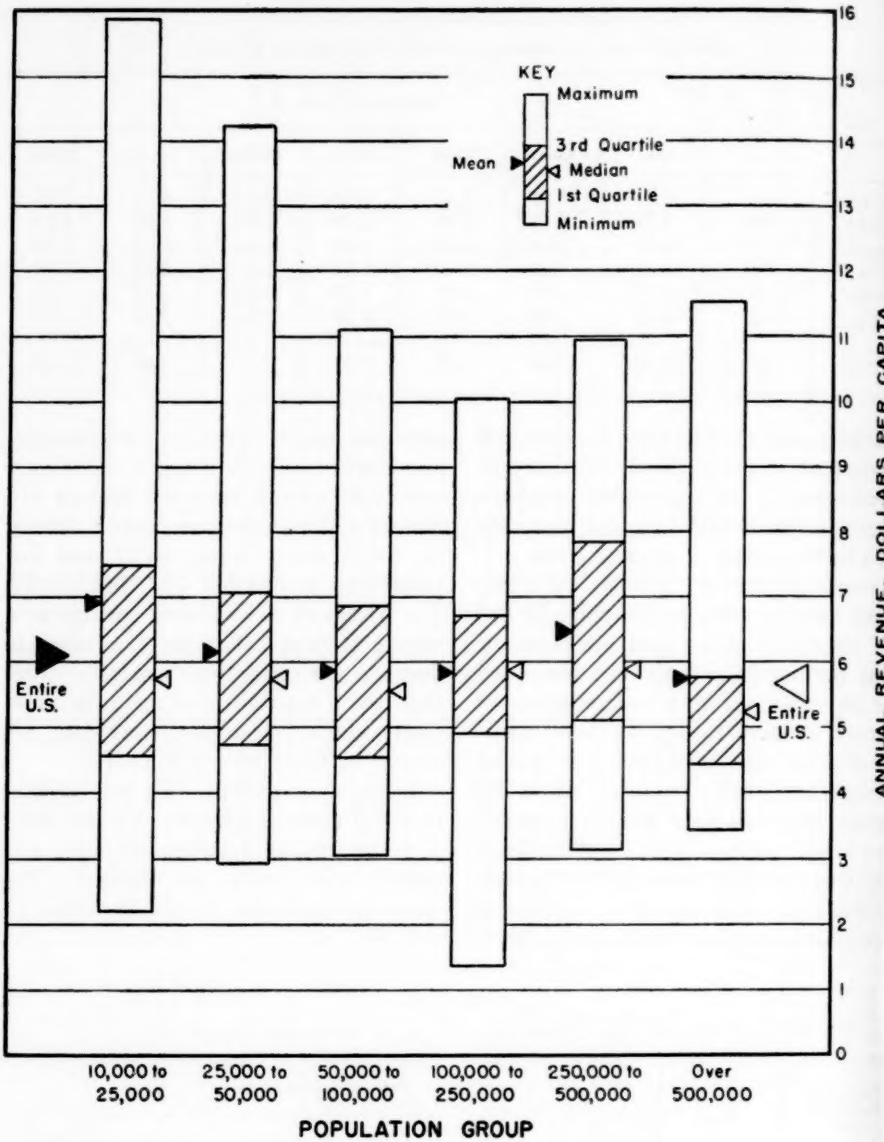

FIG. 18. Revenue, by Population Groups

The mean values of operation and maintenance costs tend to decrease with an increase in population. The same is true of the median values for all groups up to 500,000 population, where a slight increase is noted. The range also decreases with increased population, but this may be caused, in part, by the relatively small number of cases in the groups of more populous cities. Based on median values, the operation and maintenance costs per capita for

TABLE 13

Book Value, by Sources of Supply

Source	No. of Cases	Per Capita Book Value—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
Streams	82	10.92	257.74	57.24	39.59	49.53	63.18	44.32
Lakes	51	7.84	437.37	61.04	39.58	52.50	64.77	60.00
Imp. Rsvr.	58	17.00	175.90	71.14	44.08	71.11	87.23	70.00
Wells	109	11.84	109.06	45.49	32.90	43.52	55.41	44.18
Springs	4	14.68	93.35	47.94				

TABLE 14

Book Value, by Population Groups

Pop. Group	No. of Cases	Per Capita Book Value—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	122	10.92	437.37	59.76	38.75	49.65	67.65	45.15
2	94	11.84	257.74	56.39	37.86	49.53	66.37	45.33
3	61	7.84	145.83	49.05	35.45	47.33	62.00	44.76
4	41	10.99	109.64	51.66	36.66	50.00	71.66	48.88
5	19	20.40	125.67	57.79	42.50	53.33	80.00	47.50
6	20	44.65	205.87	70.71	52.20	57.77	75.00	52.50
U.S.	357	7.84	437.37	56.73	38.33	50.01	66.14	45.68

TABLE 15

Book Value, by Production Groups

Per Capita Production *gpd.*	No. of Cases	Per Capita Book Value—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
40– 90	96	7.84	437.37	48.54	31.87	44.40	56.25	45.00
90–140	138	10.99	109.06	51.38	40.00	49.45	65.71	45.91
140–190	59	10.92	205.87	61.27	42.73	56.36	69.17	62.67
190–240	18	18.70	145.83	66.11	50.00	63.33	77.50	70.00
240–290	12	36.56	210.44	95.83	45.00	65.00	135.00	
290–340	5	30.82	129.48	73.00		75.00		
340–400*	4	24.37	63.19	42.50		40.00		
540–590	1			75.79				

* Enlarged to include one value of 394 gpd. per capita.

city of 300,000 population is approximately 71 per cent of that for a city of 20,000.

Production groups. Both production figures and operation and maintenance costs were reported by 384 cities. Production groups with a range of 50 gpd. per capita (*see* Table 12) were arbitrarily chosen, except for the higher production values. Generally speaking,

TABLE 16

Revenue, by Sources of Supply

Source	No. of Cases	Per Capita Revenue—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
Streams	92	2.19	14.22	6.32	4.55	6.00	7.43	5.80
Lakes	64	2.65	9.99	5.50	4.50	5.54	6.30	5.71
Imp. Rsvr.	69	1.37	15.86	7.02	5.00	6.42	8.50	5.80
Wells	125	2.31	14.39	5.72	4.46	5.23	6.50	4.80
Springs	4	3.38	5.28	4.40				

TABLE 17

Revenue, by Population Groups

Pop. Group	No. of Cases	Per Capita Revenue—$						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	158	2.19	15.86	6.90	4.58	5.71	7.50	4.74
2	104	2.92	14.22	6.13	4.71	5.73	7.07	5.69
3	68	3.06	11.12	5.85	4.55	5.56	6.86	4.79
4	46	1.37	10.05	5.81	4.90	5.85	6.72	5.81
5	20	3.11	10.96	6.49	5.09	5.87	7.83	
6	22	3.42	11.52	5.72	4.42	5.24	5.74	
U.S.	418	1.37	15.86	6.10	4.63	5.68	7.09	5.25

TABLE 18

Rate Schedules

Use *1,000 cu.ft.*	No. of Cases	Monthly Rate—*$/1,000 cu.ft.*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
1	416	0.18	10.74	1.93	1.45	1.88	2.45	1.63
10	416	0.17	4.67	1.43	1.02	1.36	1.81	1.07
100	413	0.12	2.50	0.98	0.69	0.91	1.26	0.75
1,000	404	0.07	2.50	0.80	0.56	0.73	1.02	0.65

the trend of mean values is toward increased per capita costs with an increase in production. The mean cost for the 180–230 group is the highest mean value for all production groups. This group also has the greatest overall and quartile ranges. Median cost values tend to rise from the low production groups to the 180–230 production group and then decrease as production increases. Mean and median values are lowest in the 80–130 group. The mean value in that group is 61 per cent of the mean for the 180–230 group. The distribution in each production group was such that the calculation of modal values of any significance was impossible. The statistical

data for this analysis are shown in Table 12 and Fig. 13.

Book Value

Of the cities in the survey, 104 did not list book value per capita (Survey Table 1, Column 8). The mean book value per capita for the 357 cities analyzed is \$56.73. The median and modal values are \$50.01 and \$45.68, respectively. The over-all range is \$7.84 to \$437.37, and the quartile range is \$38.33 to \$66.14. The book values listed in the survey are for the entire water supply system with no breakdown into distribution systems and purification plants. Neither is it possible to know the depreciation or the type of purification, if any, provided. These factors, plus the fact that the population figures are estimated and that the water produced is not necessarily up to the limit of plant capacity, make detailed mathematical analysis of the data inadvisable.

Source of supply. Of the 446 cities listing a source of supply, 84 did not report book value per capita. This number, plus the 58 cities which listed a combined source of supply, reduces the number of cities in this analysis to 304. The statistical data are shown in Table 13 and Fig. 14. Impounding reservoirs have the highest book value per capita of the five groups. Cities using ground water supplies have systems of lower book value than cities which use surface waters. The book

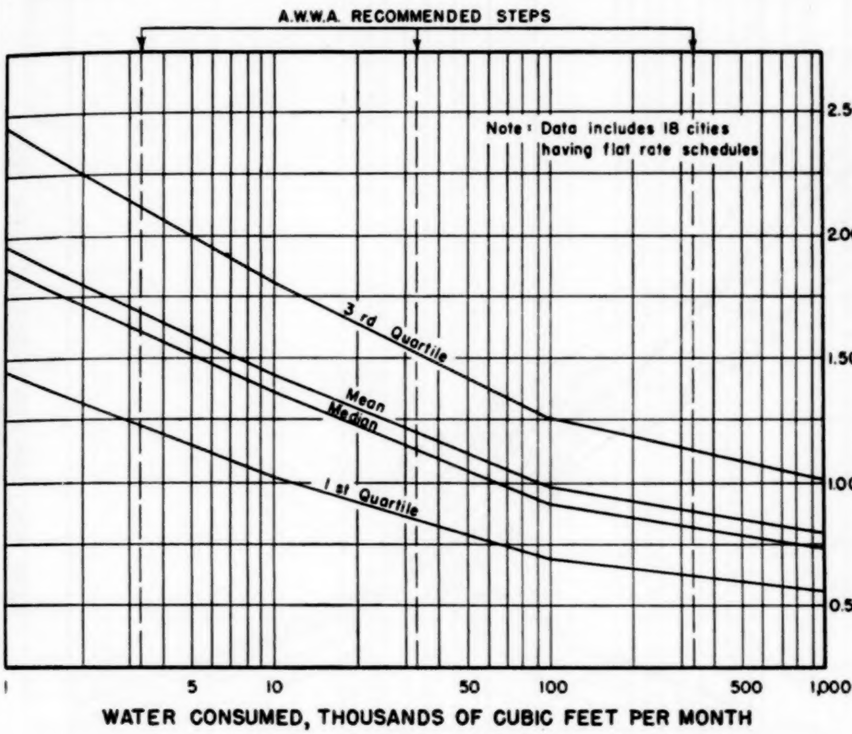

FIG. 19. Rate Schedules, 404 U.S. Cities *

* Includes 18 with flat rates.

value for a well supply, based on mean values, is 64 per cent of the book value for an impounding reservoir supply. The greatest over-all range in values occurs in the lake supply group, the extremes being $7.84 and $437.37. Of the four large groups, well supplies have the smallest range in values, $11.84 to $109.06. Impounding reservoirs, while having the highest mean value, present the smallest range of the three surface supplies.

Population groups. This analysis covers 357 cities. The lowest mean and median book values per capita occur in the 50,000–100,000 population group. Median values per capita are more or less constant for cities of up to 100,000 population and then rise to a high value for cities larger than 500,000. Based on median values, the book value per capita for the 50,000-100,000 population group is 82 per cent of the value for cities of more than 500,000 population. One reason for the rise in book value with population is that larger cities usually depend on surface supplies which are more costly

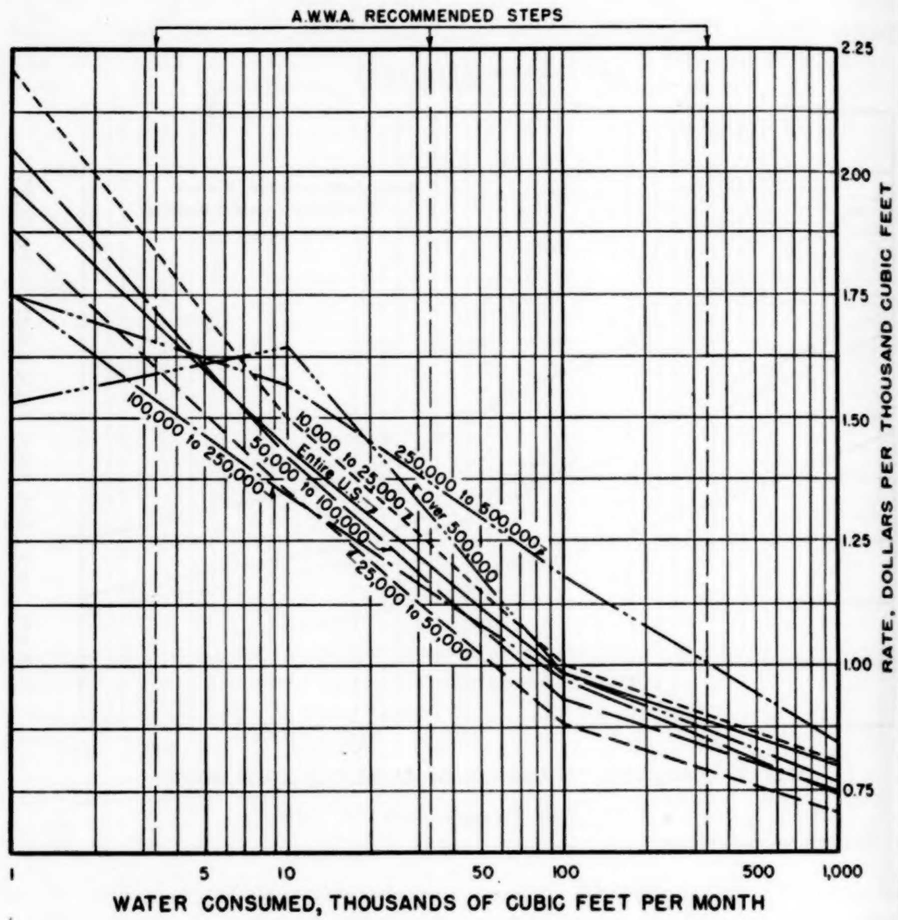

FIG. 20. Mean Rate Schedules, by Population Groups

than ground water supplies. The statistical data are shown in Table 14 and Fig. 15.

Production groups. The relation between book value and production is shown in Table 15 and Fig. 16. The per capita production figures were classified into eight groups of equal range. Based on median values, the book value increases with increased production up to the 340–400 group, at which point a drop occurs. The mean values increase up to the 290–340 group and then drop. Values of production above 300 are somewhat unusual, and therefore a trend similar to that of the more common values is not to be expected. The mean value for the 40–90 production group is 51 per cent of the mean value for the 240–290 group. The three highest production groups do not include enough cases for a determination of quartiles and modes.

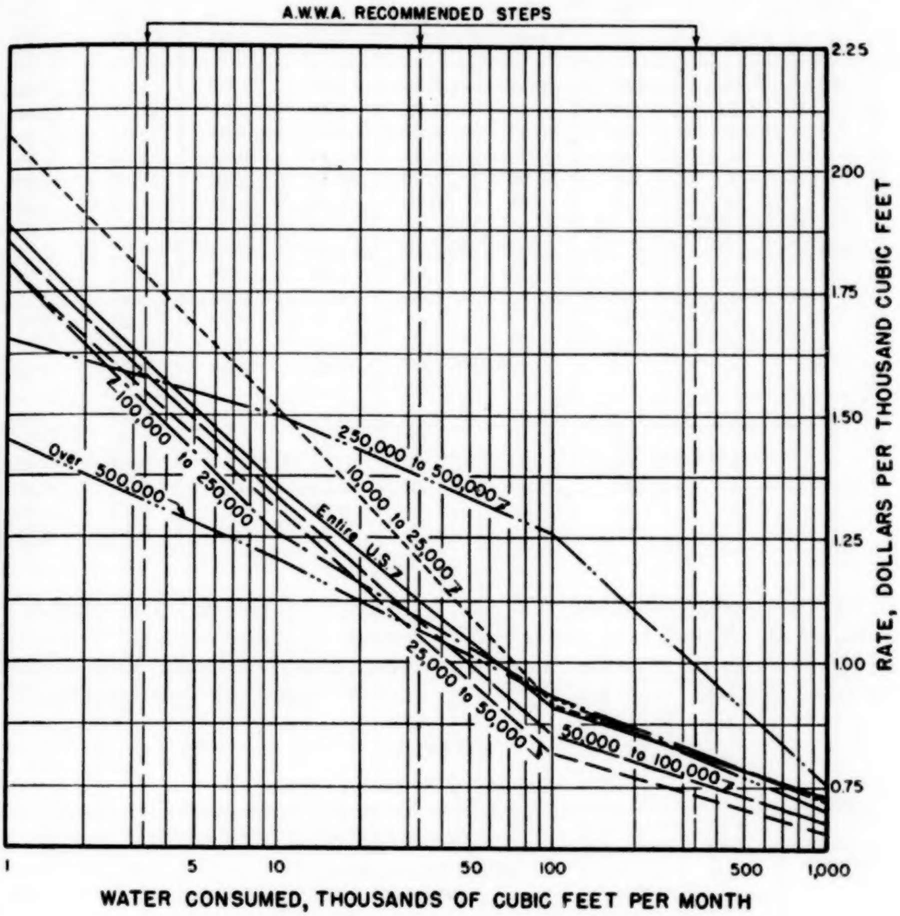

FIG. 21. Median Rate Schedules, by Population Groups

Revenue

Information on revenue per capita is given by 418 cities in the survey. The mean value for those cities is

TABLE 19

Rate Schedules, by Population Groups

Use *1,000 cu.ft.*	Pop. Group	No. of Cases	Monthly Rate—*$/1,000 cu.ft.*					
			Min.	Max.	Mean	1st Q.	Median	3rd Q.
1	1	137	0.18	10.00	2.21	1.62	2.07	2.82
	2	96	0.86	3.50	1.88	1.41	1.81	2.39
	3	64	0.43	10.74	2.05	1.25	1.85	2.50
	4	40	0.75	3.30	1.75	1.20	1.81	2.75
	5	20	0.90	3.00	1.75	1.25	1.66	2.15
	6	17	0.68	2.75	1.53	1.00	1.45	2.20
10	1	137	0.17	3.28	1.50	1.05	1.51	1.96
	2	96	0.40	2.93	1.35	0.94	1.31	1.68
	3	66	0.43	4.67	1.42	1.03	1.33	1.69
	4	40	0.70	2.35	1.34	0.93	1.26	1.80
	5	20	0.90	2.50	1.57	1.18	1.50	1.90
	6	17	0.65	6.75	1.64	0.92	1.21	2.15
100	1	135	0.02	2.50	1.00	0.65	0.92	1.24
	2	93	0.20	2.06	0.88	0.69	0.82	0.96
	3	66	0.40	1.73	0.93	0.70	0.85	1.17
	4	39	0.17	1.62	0.97	0.72	0.93	1.33
	5	20	0.63	1.80	1.18	0.88	1.26	1.43
	6	17	0.17	1.97	0.98	0.68	0.93	1.18
1,000	1	132	0.07	2.50	0.82	0.53	0.73	1.02
	2	94	0.10	2.01	0.71	0.53	0.66	0.82
	3	64	0.23	1.52	0.74	0.54	0.68	0.90
	4	38	0.09	1.60	0.74	0.60	0.72	0.87
	5	19	0.40	1.58	0.84	0.64	0.76	1.00
	6	17	0.44	1.29	0.77	0.54	0.70	0.97

$6.10, the median is $5.68 and the mode, $5.25. Values range from $1.37 to $15.86, with the quartile range being $4.63 to $7.09.

Source of supply. The analysis of revenue by source of supply covers 354 cities. Based on mean values, the revenue is lowest for lake supplies and

TABLE 20

Rate Schedules, by Production Groups

Per Capita Production *gpd.*	No. of Cases	Monthly Rate for 10,000 cu.ft.—*$/1,000 cu.ft.*						
		Min.	Max.	Mean	1st Q.	Median	3rd Q.	Mode
30– 80	76	0.30	3.03	1.81	1.52	1.80	2.03	1.56
80–130	167	0.17	3.28	1.45	1.11	1.40	1.81	1.15
130–180	74	0.61	2.40	1.23	0.71	1.17	1.53	1.20
180–230	20	0.68	4.67	1.29	0.78	1.05	1.40	
230–280	11	0.60	2.10	1.22	0.80	0.95	1.75	
280–330	5	0.87	1.14	0.97		0.90		
330–400	6	0.46	0.91	0.77		0.80		
530–580	1			1.06				

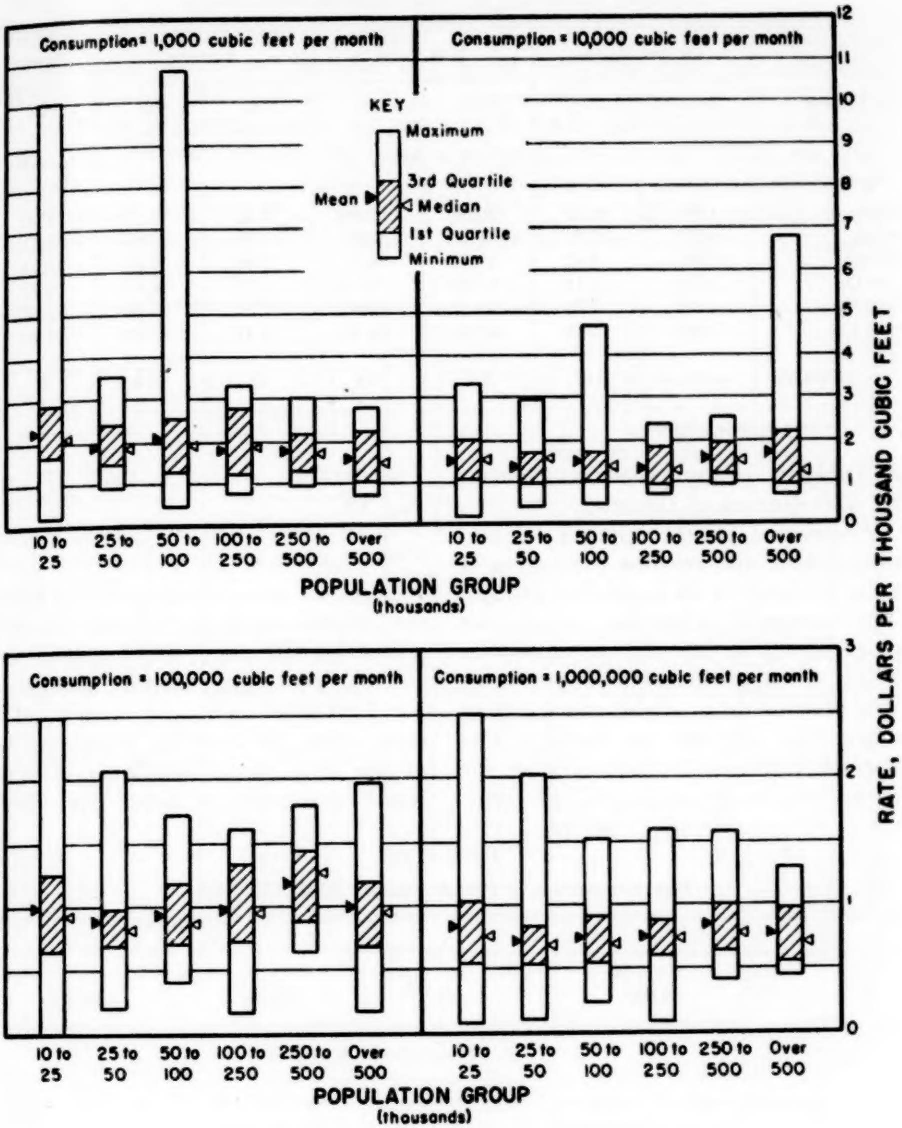

Fig. 22. Rate Schedules, by Population Groups

highest for impounding reservoirs. Based on median values, well supplies have a slightly lower revenue than lake supplies. Taking the median value for impounding reservoirs as 100 per cent, the median for streams is 94 per cent; for lakes, 86; and for wells, 82 per cent. The mean value for springs is the lowest of all the five groups, but only four cities listed springs as a source, too few for the computation of the remaining statistical information

TABLE 21

Financial Comparison of Private Systems With All U.S.

Item	Op. and Maint.		Book Value		Revenue		Taxes*
	Pvt.	U.S.	Pvt.	U.S.	Pvt.	U.S.	Pvt.
	$ per capita						*per cent*
Min.	1.30	0.81	30.08	7.84	2.65	1.37	5.93
Max.	6.22	15.91	145.83	437.37	12.89	15.86	37.61
Mean	3.48	3.02	59.76	56.73	7.66	6.10	19.14
1st Q.	2.22	2.11	43.97	38.33	5.73	4.63	9.28
Median	2.68	2.73	56.30	50.01	7.29	5.68	16.65
3rd Q.	3.90	3.66	63.65	66.14	9.44	7.09	25.59
No. of Cases	30	417	23	357	32	418	37

* Per cent of total revenue.

in Table 16. Figure 17 shows the data for this portion of the study.

Population groups. Based on median values, the revenue per capita is quite uniform for all population groups. The variation in median values for cities of up to 500,000 population is $0.31, or approximately 5 per cent. The revenue drops slightly for cities of more than 500,000 population. The over-all variation in median values for all population groups is 10.7 per cent. The data are shown in Table 17 and Fig. 18.

Rates

Rates for water consumption of 1,000 and 10,000 cu.ft. per month are reported by 416 cities; 413 list rates for 100,000 cu.ft. per month; and 404, for 1,000,000 cu.ft. per month. Of these cities, 18 have flat rates. Many of the cities have additional charges based on demand or meter size. Dis-

TABLE 22

*Rate Comparison of Private Systems With All U.S.**

Item	Consumption—*cu.ft.*							
	1,000		10,000		100,000		1,000,000	
	Monthly Rate—*$/1,000 cu.ft.*							
	Pvt.	U.S.	Pvt.	U.S.	Pvt.	U.S.	Pvt.	U.S.
Min.	1.25	0.18	0.40	0.17	0.20	0.12	0.10	0.07
Max.	3.75	10.74	3.06	4.67	2.10	2.50	2.10	2.50
Mean	2.43	1.97	1.67	1.43	1.21	0.98	0.94	0.80
1st Q.	1.95	1.45	1.29	1.02	0.94	0.69	0.66	0.56
Median	2.46	1.88	1.60	1.36	1.21	0.91	0.83	0.73
3rd Q.	2.90	2.45	2.09	1.81	1.50	1.26	1.10	1.02
No. of Cases	38	416	38	416	37	413	35	404

* Private utility rates are shown as charged, without deductions for taxes and the like.

counts for prompt payment or penalties for late payment are also included by many cities in their rate structures. As in the survey, these items are not taken into account in the following analysis.

Population groups. The rate data for all cities is shown in Table 18 and studies. Median values run from about $1.90 per 1,000 cu.ft. for 1,000-cu.ft. consumption per month to $0.75 per 1,000 cu.ft. for 1,000,000-cu.ft. consumption per month. Using the three-rate schedule recommended by the A.W.W.A. in 1923, the median rate for 10,000-cu.ft. consumption per month

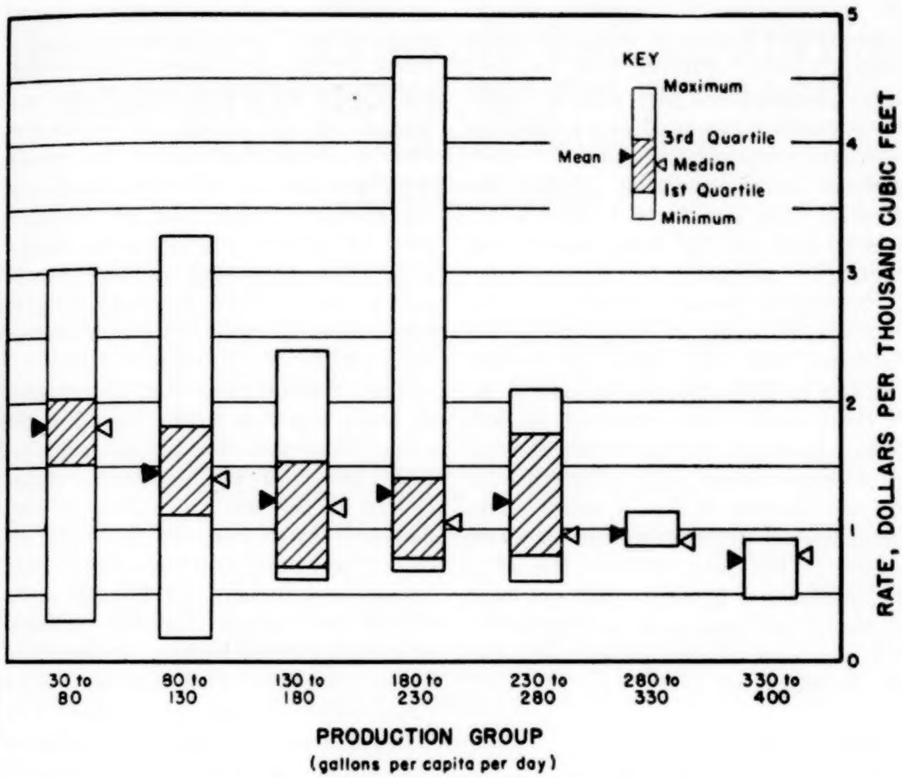

Fig. 23. Rates for 10,000-cu.ft. Consumption per Month, by Production Groups

Fig. 19. In accordance with the usual rate structures, the rate per 1,000 cu.-ft. of water used decreases with increased consumption. The mean and median rates for each population group are plotted against consumption in Fig. 20 and 21 respectively. The same general trend shown for all cities in Fig. 19 is evident in the population group falls between the first and second steps; the rate for 100,000 cu.ft. falls between the second and third steps; and the rate for 1,000,000-cu.ft. consumption falls after the third step. These statements also hold for the recommended four-rate schedule, which places a fourth step at 3,000,000-cu.ft. consumption.

The relation between rates and population is further shown in Table 19 and Fig. 22. The distribution of cases did not permit the calculation of modal values of any significance. For a consumption of 1,000 cu.ft. per month, the trend is toward lower rates in the larger cities. The same is true for a consumption of 10,000 cu.ft., except in the 250,000–500,000 population group. For a 100,000-cu.ft. consumption, the rates are fairly uniform, with the previous exception of the 250,000–500,000 population group. For a 1,000,000-cu.ft. consumption, the rates are quite uniform for all population groups. In general, there is a trend toward a decreased unit rate for large users in all population groups.

Production groups. Rates for the first 10,000 cu.ft. of water used are compared with per capita production of water in Table 20 and Fig. 23. Both of these items were reported by 360 cities. Based on median values, the use of water increases with a decrease in the cost of water to the consumer. The same general trend is evident for mean values. The mean rate for the 330–400 production group is 42.5 per cent of the mean rate—and production is 627 per cent of the production—for the 30–80 group.

Privately Owned Systems

The survey lists 43 privately owned water supply systems, one of which has a population of less than 10,000 and is therefore neglected in this analysis. The population of the other 42 cities ranges from 13,000 to 616,000, the mean being 148,285. The statistical analyses of operation and maintenance costs, book value, revenue and taxes paid for private supplies and for all United States cities listed are shown in Table 21; the rates for private supplies and for all cities listed are shown in Table 22.

The median per capita operation and maintenance costs for privately owned supplies are 2 per cent lower than that value for all cities listed. The median per capita book value is 13 per cent higher, and the median per capita revenue is 28 per cent higher, for private supplies than for all cities listed. If the median revenue for private supplies ($7.29) is reduced by the median value of the percentage of total revenue paid in taxes (16.65 per cent), a figure approximately equal to the median revenue for all cities listed is obtained.

The median rates for all amounts of water used are lower for all of the cities listed than for private supplies. For 1,000 cu.ft. used, private supplies charge 31 per cent more than the median rate for all cities listed; for 10,000 cu.ft., the rates for private supplies are 18 per cent higher; for 100,000 cu.ft., 33 per cent higher; and for 1,000,000 cu.ft., 14 per cent higher. It should be noted, however, that private utility rates must include an amount (*see* Table 21) to cover the taxes levied on the utility by the various units of government.

Reference

1. A Survey of Operating Data for Water Works in 1945. A.W.W.A. Report. Jour. A.W.W.A., **40**:167 (Feb. 1948).

Tentative

Recommended Practice

for

INSPECTING, REPAIRING AND REPAINTING ELEVATED STEEL WATER STORAGE TANKS, STANDPIPES AND RESERVOIRS

This "Tentative Recommended Practice" is based upon competent experience and is intended for use under normal conditions. The procedure is not intended for unqualified use under all conditions. The propriety of following this procedure in any water utility must be reviewed by the authorities responsible for the construction and maintenance of water works facilities in the locality concerned.

Approved as Tentative by:
New England Water Works Association, Sept. 14, 1948
American Water Works Association, Sept. 20, 1948
American Welding Society, *in process*

First Printing, October 1948

AMERICAN WATER WORKS ASSOCIATION
Incorporated

500 Fifth Avenue, New York 18, N.Y.

Table of Contents

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Tentative Recommended Practice for

Inspecting, Repairing and Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs

Introduction

This document has been prepared by a joint committee of the American Water Works Assn., the New England Water Works Assn. and the American Welding Society. In developing this "Recommended Practice" document, covering the inspection and/or repair and/or repainting of elevated water storage tanks, standpipes and reservoirs, the associations make available to their members an outline of methods which, in the opinion of their committees, may properly be followed.

The principles which the committees feel that the tank * owner should follow in repairing or painting an elevated water tank are listed below. When the term "owner" is used, it may be taken to mean the person or corporation owning the works; the manager or superintendent of the water department or company; the water board or commission; the city council; or the mayor; that is, whoever is responsible for contracts made by and on behalf of the water utility, whether publicly or privately owned.

1. The tank owner should employ a disinterested inspector to look over the metal surface inside and out, to determine the condition of the paint and interior metal surfaces, and what repairs, if any, are needed. Tanks need repainting frequently, but, if properly maintained, repairs are rarely necessary.

2. The owner should invite any tank painting or repair firm which he wishes to bid on a job to inspect the tank at the same time the inspector does, so that the prospective contractors have full information concerning the conditions.

3. The owner should have the tank drained, cleaned and dry, ready for inspection, on the announced date. (*See* Part A, Sec. 2A–1.4.)

4. The owner should draw up his own proposals for the work to be done and request bids on the work. He should have these proposals approved by his attorney.

5. The tank owner should not combine proposals for repair work and painting in one document. He should always leave himself free to award separate contracts if he desires.

6. The owner should not permit any bidder to condition one part of the operations upon another part. For example, the owner should not permit a painting contract to bear any conditions, reservations or cancellations of customary guarantees dependent upon the same bidder receiving the contract for repairs.

* The word "tank" is used hereinafter broadly in place of the lengthy phrase "elevated steel water tanks, standpipes and/or steel water storage reservoirs."

7. The owner should, however, include in his proposal a provision that, if the contracts for repairs and for painting are granted to the same contractor, the contractor shall record the amount which he will deduct from the sum of the two independent bids. (The price for the combination job should be less by the stated amount than the sum of the same contractor's bids for separate jobs.)

8. The owner should compare all bids received to see whether a separate bid by one contractor for repair and a separate bid by another contractor for painting total less than the adjusted bid in 7 above. If the saving is material and if both the contractors are known to be reliable, separate contracts should be let.

9. The owner, particularly if a municipal department, should arrange for public review of bids and for public letting of contracts.

10. If the owner chooses to engage in letting contracts for painting and repair on contract forms other than his own, he should first submit them to his attorney, asking him to study them carefully to see:

a. that no unlimited unit price commitments are included in the contract form;

b. that no commitments or guarantees by the contractor are conditioned upon any matters not clearly and specifically set forth in the contract;

c. that no obligations are incurred by the owner which are not specifically set forth in the contract; and

d. that a clause covering possible extra work is included in the contract form and is of the same general character and equally as specific as that included in Sec. 2B–2 of the "Recommended Practice for Repairs" (Part B of this document).

Referring to 10a above, it is clearly in the interest of equitable business practice that, if the owner and the contractor agree to permit or authorize the contractor to do some unscheduled repair work incidental to painting, this repair work should not be of such extent as to make the painting cost minor by comparison. Again, upon the assumption that a tank owner may choose to disregard the recommendations for prior inspection outlined above, he can properly, and should, stipulate that the total of unscheduled repairs shall not cost more than a given amount, such as the total of the painting contract.

Referring to 10b and 10c above, it is observed that, if extended beyond one year, guarantees of repair or painting work done involve uncertainties which are not necessarily in the interest of either the tank owner or the repair or painting contractor. Frequent and periodic inspection of a water tank is proper and useful, but it should not result in the owner's commitment to a contract for work to be done at an uncertain future date or at a price not arrived at by proper competition.

Since this document relates primarily to painting, the body of the text includes no reference to other methods of protecting metal surfaces.

The electric (cathodic) method of protecting the submerged area of water tank interiors by the use of electrodes suspended in the water has proven satisfactory under most conditions when properly designed, installed and maintained. Cathodic protection failures have occurred principally in cold climates where ice has dislodged the electrodes, or in tanks storing waters with wide fluctuations in alkalinity. Cathodic protection, like specific paints, has varying applicability to various waters.

If contemplated for inside protection, the equipment should be selected only after technical consideration of the particular water to be stored. A combination of cathodic protection and painting of the surface ordinarily gives the best results. When calling for bids on cathodic protection systems, bidders should be asked to state the capacity of the power unit and the material, number and length of electrodes to be used.

By the issuance of this procedural document, it is not implied that water departments or companies are not, on their own initiative, competent to develop equitable contracts. Neither is it implied that any member of the associations involved is required to use the procedure herein outlined. The associations have no power or intent to stipulate that a precise procedure must be followed in any phase of water works operation and maintenance. The associations, likewise, are not in a position to police the entire field of contractual operations of water departments and companies. They must content themselves with providing for their members what is considered the best information available on any subject which is documented. It must remain with the responsible executives in the water department or company to protect the interest of the community which they serve.

Part A 7H.2-T

Tentative Recommended Practice for

Inspecting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs

Section 2A-1—General

Sec. 2A-1.1—Scope

Every elevated steel water tank, standpipe or reservoir should be carefully inspected prior to repair and/or repainting and at any time when leakage or some other apparent deterioration is observed. In any event, all elevated water tanks should be thoroughly inspected at intervals of not more than five years. It is the intent of this document to define the requisite qualifications of the inspecting agency, the type of inspection to be made and the data considered essential.

Sec. 2A-1.2—Inspection Service

Under the terms of this recommended practice document, inspection service shall be provided only by organizations or individuals who are properly qualified to do such work. Those so qualified are:

(1) An engineering organization whose principals are registered professional engineers, specializing in inspection service and having at least five years' experience in the inspection of steel structures

(2) Independent engineers, licensed in the state in which the structure is located, whose practice has included substantial or major attention to steel construction

(3) Inspection or safety agencies of the state in which the structure is located, if such agencies are empowered to render inspection service and, further, if such inspection services involve the employment of personnel experienced in steel construction and maintenance.

In all of the above classes of qualified inspection agencies, the inspector or inspectors assigned to the work in the field shall have been properly trained by the organization so qualified and shall have no interest, other than that of a competent inspector, in the performance of any work under consideration at the time the inspection is made.

Sec. 2A-1.3—Responsibility

The inspector shall assume the entire responsibility for accident to himself while inspecting the structure. He shall make such observations of ladders, railings, roof rods and other parts of the structure as may be necessary to determine their safety for use by him in inspecting the structure. The inspecting company or inspector shall carry adequate workmen's compensation, property-damage and public-liability insurance and shall fully protect

the owner against claims of any nature arising out of the inspection work.

Sec. 2A-1.4—Draining of Tank

The owner, following proper notification, shall have the tank emptied for the inspector in order that the inside of the roof, sides and bottom of the tank will be properly exposed for inspection. The inside surfaces shall be thoroughly washed down by the owner, who shall have all slime removed from wall surfaces and loose deposits and dirt removed from the tank bottom before the inspector arrives. *This is essential.*

Sec. 2A-1.5—Work Included

The work included under this inspection shall consist of: (1) a field examination; and (2) a specific report upon the structure, using the information form which is a part of this document (Sec. 2A-2 and 2A-3) supplemental wherever necessary to fit peculiar local conditions. The inspection work does not include repairs, *except* that, if cotter pins or nut pins are found to be missing, they shall be replaced at once, or else a special report shall be made promptly to the owner so that he may have the pins replaced.

TABLE 1

Pitting Report

Location (by plates numbered from roof down)	Per Cent of Area Affected (approx.)	Max. Depth of Pitting Found	Type of Pitting	Plate Thickness
1 2 3 etc. bottom				

Section 2A-2—Examination and Report

Sec. 2A-2.1—Condition of Paint

Under the general heading "Condition of Paint," give a description of the condition of the paint as found, stating:

(1) Approximate per cent of rust area

(2) Special locations of such areas, if segregated

(3) Character of such rust areas—that is, whether general or blotchy corrosion, loose paint or none

(4) Whether the rust can be removed by wire brushing, to provide a satisfactory surface for painting.

Sec. 2A-2.2—Pitting

Determine and report upon the extent and depth of pitting. The extent should be described both as to location and character. The record of depth of pitting should be specific as to location, area affected, whether blotchy, deep, pin-point or general corrosion. Depth gages should be used to obtain specific data. Report as in Table 1.

If plates are badly pitted, report whether drilling holes to determine the plate thickness is recommended.

Sec. 2A-2.3—Type of Repairs

Where pitting has penetrated to a depth indicating the necessity for repairs, the report shall so state specifically, describing the location of such spots and their size. If they can be repaired by patches, the inspector shall specify the size, location and number

of patches. If other types of repairs are indicated, the inspector shall specify clearly the type and extent recommended. (Use the same plate reference numbers as in Table 1.) The inspector, in his report, shall inform the owner of all repair work which he considers necessary. The report need not be limited to the items specifically outlined herein, but should include all items of any nature which the inspector considers material.

Section 2A-3—Detailed Report of Inspector

Sec. 2A-3.1—Items to Be Reported

In addition to the descriptive report outlined under Section 2A-2, the inspector shall report on the details itemized below.

3.1.1—Anchor Bolts

(1) Are the anchor bolts rusted so as to reduce their strength materially? If so, caliper and record the smallest section. Advise replacement if considered necessary.

(2) Are the anchor bolt nuts tight?

3.1.2—Column Shoes

(1) Are the column shoes clean and painted?

(2) Has dirt accumulated?

(3) Are the column shoes seriously rusted? If so, where and to what depth?

3.1.3—Tower

(1) Are the tower posts in line?

(2) Is there any indication of settlement in the foundations?

(3) Are the tower rods in good adjustment and well turned up?

(4) Are the tower rods in good condition? If badly rusted, measure the smallest part and report, indicating rods on which reduced section occurs. (Advise replacement if considered necessary.)

3.1.4—Cotter Pins

(1) Examine each pin for the presence of cotter pins. Report the location of any pins not so fitted.

(2) Where rod pins with nuts are used, advise if the nuts are on with full thread and the end of the thread is well battered.

3.1.5—Riser Pipe

(1) Is the riser pipe straight?

(2) Are the riser pipe stay rods in good condition?

(3) Is the frost casing in good condition and properly supported?

3.1.6—Indications of Leakage

(1) Are there any indications of leakage in the riser pipe?

(2) In the expansion joint?

(3) In the tank proper? If so, give the location and state the type of repair indicated.

3.1.7—Ladder

Is the ladder safe?

3.1.8—Balcony

(1) Is the balcony safe?

(2) Is the balcony floor in good condition?

(3) State the amount of rust accumulated on the balcony floor.

3.1.9—Bolts

Are any bolts or rivets omitted or missing in the spliced connections of the tower, struts and balcony?

3.1.10—Paint

Report on each of the following items:

(1) The condition of the paint and metal of the tower

(2) The condition of the paint and metal on the outside of the tank bottom, particularly underneath the balcony and post connections

(3) The condition of the paint and metal outside of the tank shell

(4) The condition of the paint and metal outside of the roof and under the eaves of the roof

(5) The condition of the paint and metal inside of the tank shell (Each sheet shall be carefully examined, removing enough of the accumulation of scale and rust to enable the inspector to report in detail the exact condition of the metal underneath and the extent of rust and pitting.)

(6) The condition of the paint and metal on the inside of the roof

(7) The condition of the spider and spider rods

(8) The finial connection. (Is it solid and safe for the attachment of the painter's trolley?)

(9) The condition of the paint and metal on the inside of the bottom

(10) The condition of the paint and metal inside of the riser pipe, particularly at the bottom.

3.1.11—Rivets

Report the condition of the rivets at lap joints and post connections.

3.1.12—Metal

Report the condition of the metal between the rivets at the laps and at the post connections.

3.1.13—Tank Bottom

Has the bottom of the tank deteriorated because of its having been covered with mud or scale? If so, what conditions are observed? Will scaling and repainting be satisfactory? Are repairs indicated? If so, describe in detail.

3.1.14—Prior Painting

(1) When was the tank last painted?

(2) What material was used?

Sec. 2A-3.2—Disposition of Report

3.2.1. Two copies of the inspection report shall be delivered to the owner.

3.2.2. It is understood between the owner and the inspection company that copies of the inspection report may be made available by the owner to painting or tank repair contractors, to define the condition of the tank, if bids for repair or painting are desired.

Sec. 2A-3.3—Payment

Payment for the above specified services, including all expenses of the inspector, shall be at the lump sum price agreed upon between the owner and the inspector. Payment shall be made within thirty days after the receipt of the inspection report.

Section 2A-4—Cleanliness

The inspector shall conduct all his work in a clean and sanitary manner.

No one shall work in a tank if he has been under a physician's care, or has needed a physician's care, within a seven-day period prior to entering or working in the tank. No person shall be permitted to work in a tank who has an abnormal temperature or gives evidence of illness. The tank owner, or a physician employed by him, shall be the judge of the physical fitness

or unfitness of any person to enter or work in a tank. No deviation from this stipulation may be permitted.

The tank owner, after work of any nature is done in a tank, is charged with satisfying himself that the tank interior is clean and sanitary before the tank is returned to service. Although a contractor may be required by his contract to clean all surfaces thoroughly before a tank is restored to service, it is the ultimate responsibility of the tank owner either to give the tank a final field inspection or to require such laboratory tests of the quality of water held (for test purposes) in the tank as will demonstrate the good sanitary condition of the tank interior. (See the note on disinfection procedure at the end of Part C of this document.)

Part B 7H.2-T

Tentative Recommended Practice for

Repairing Elevated Steel Water Storage Tanks, Standpipes and Reservoirs

Introduction

Every tank repair job should be preceded by a detailed inspection of the structure and a report by a competent inspector. Part A of this document deals with inspection. Only from such an inspection is it possible for the tank owner to determine the character and extent of the repairs needed. Without such a determination, it is impossible to define the repair work to be done so that prospective bidders can estimate the cost of the repairs and submit economical proposal therefor.

The owner, using the inspector's report as a basis, shall define and list the repairs to be made. Bids should be made on a fixed-price basis.

It is recognized that specifications for repair work must necessarily be rather general, but the following is recommended as likely to secure good work from responsible bidders at reasonable and definite cost.

Section 2B-1—General

Sec. 2B-1.1—Work to Be Done

The specifications and contract shall cover all repair work to be done and all compensation to be paid or received therefor. There shall be no other agreements relating either to the work or to compensation.

Sec. 2B-1.2—Inspection Recorded

The owner shall advise that he has had the structure inspected (naming the inspector) and that a copy of the inspection report is available. The bidders shall familiarize themselves with the report and the conditions of the

structure, and, upon request to the owner, may make such further inspection as they consider necessary, prior to submitting proposals.

Sec. 2B–1.3—Work to Be Itemized

The owner shall itemize repair work by units, such as the number of patch plates to be welded to the structure and their average area; the lineal feet of welding to make the seams watertight; the spider rods to be replaced; the new roof or parts to be replaced, and so forth.*

It is recommended that, in general, welding on tank plates to replace impaired thickness be limited to filling of pits; and that extensive welding over the surfaces of plates or of riveted seams be carefully considered and used only where replacement will not be practicable. All welding performed in the replacement of plates or broken parts, or for other repairs, shall be performed in accordance with the welding provisions given in A.W.W.A.-N.E.W.W.A.-A.W.S. Standard Specifications for Elevated Steel Water Tanks, Standpipes and Reservoirs (7H.1–1943).

Sec. 2B–1.4—Lump Sum Bids

Bids shall be on a lump sum basis, including all the contractor's costs, such as transportation, labor, tools, equipment, insurance, delays or other costs of any nature growing out of the repair work above defined.

Section 2B–2—Extra Work

No payment shall be made for any work other than the lump sum amount bid by the contractor, except upon written order of the owner or his authorized representative, *prior to the beginning of the work for which extra compensation is to be requested.* When extra work is so authorized, compensation therefor shall consist of actual wages paid to labor thereon; plus the actual cost of materials used in the extra work; plus an allowance equal to 25 per cent of the sum of this labor and material cost, which percentage shall be the only amount to be paid in addition to said costs. No claim for equipment rentals, delays, insurance and similar items shall be made or allowed. All such items are embraced in the 25 per cent to be allowed as stated above.

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* *Rivets—For a great many years, it was the custom for tank manufacturers to drive tank rivets with flat heads on the inside. After a number of years, a flat-head rivet, which may have rusted to some extent, appears to have lost the major portion of its head, when, in reality, only a small part has disappeared and the rivet has many years of life left. As rivets do their work in shear and as there is very little tension force on a rivet, the head can rust nearly away before replacement is necessary. As long as a rivet stays tight in its hole, it fulfills its function and does not have to be replaced.*

Section 2B-3—Watertightness

All work shall be done by experienced workmen, using equipment best adapted to the work. Upon completion of the repair work, the structures shall be watertight. Repair work shall be neatly done. Payment for repair work shall not be made until and unless the job is watertight.

Section 2B-4—Responsibility

The contractor shall carry adequate insurance—property, public and employers' liability—and shall protect the owner against suits of any nature which may arise out of work performed by the contractor.

Section 2B-5—Inspection

The owner shall inspect the repair work as it is being done or employ an inspector to do so. Payment for work done shall be made only after the owner has satisfied himself directly that the work is satisfactory; or after an inspector's report has been filed with the owner certifying that the work has been done properly and in accordance with the terms of the contract.

It is in the mutual interest of the owner and the contractor that such inspection be made promptly.

Section 2B-6—Cleanliness

The contractor and all workmen employed by him shall conduct all operations in a clean and sanitary manner. No nuisance shall be committed in a tank; the workmen shall either use proper waste receptacles or leave the tank whenever necessity arises.

No one shall work in a tank if he has been under a physician's care, or has needed a physician's care, within a seven-day period prior to entering or working in the tank. No person shall be permitted to work in a tank who has an abnormal temperature or gives evidence of illness. The tank owner, or a physician employed by him, shall be the judge of the physical fitness or unfitness of any person to enter or work in a tank. No deviation from this stipulation may be permitted.

The tank owner, after work of any nature is done in a tank, is charged with satisfying himself that the tank interior is clean and sanitary before the tank is returned to service. Although a contractor may be required by his contract to clean all repairs thoroughly before a tank is restored to service, it is the ultimate responsibility of the tank owner either to give the tank a final field inspection or to require such laboratory tests of the quality of water held (for test purposes) in the tank as will demonstrate the good sanitary condition of the tank interior. (See the note on disinfection procedure at the end of Part C of this document.)

Part C 7H.2-T

Tentative Recommended Practice for

Repainting Elevated Steel Water Storage Tanks, Standpipes and Reservoirs

Section 2C-1—General

Sec. 2C-1.1—Repairs Not Included

Painting contracts shall cover no repair work. No payments for repair work shall be made under painting contracts.

Sec. 2C-1.2—Damage to Tank

The painting contractor shall use care in his work not to injure the tank in any way. He shall use no hammer on the tank in excess of 3 lb. in weight. If, in the process of removing old paint or carrying out the work specified in the contract, any leaks develop, they shall be repaired by the painting contractor without additional remuneration; or, if the owner so elects, by another contractor to be employed and paid by the owner. In the latter case, it is expressly understood that the painting contractor shall not claim, nor shall the owner be liable, for costs resulting from the delay in having the repair work done, but the owner shall use diligence in having the repair work done promptly.

Sec. 2C-1.3—Work to Be Done

The contractor shall commit himself to furnish all labor, machinery, tools, rigging, brushes and all cleaning and painting materials necessary to clean and paint the structure in strict conformity with the requirements of the specifications.

Sec. 2C-1.4—Inspection Recorded

The owner shall state that he has had the structure inspected, naming the inspector. The inspector's report on the condition of the structure shall be made available to bidders. The owner, upon request, may given prospective bidders ample opportunity to conduct their own inspection in order to verify the inspection covered by the report.

Sec. 2C-1.5—Lump Sum Bids

Bids shall be on a lump sum basis, including all the contractor's costs, such as transportation, labor, tools, equipment, materials, insurance, delays or other costs of any nature growing out of the painting work above defined.

Sec. 2C-1.6—Extra Work

No payment shall be made for any work other than the lump sum amount bid by the contractor, except upon written order of the owner or his authorized representative, *prior to the beginning of the work for which extra compensation is to be requested.* When extra work is so authorized, compensation therefor shall consist of the ac-

tual wages paid to labor thereon; plus the actual cost of materials used in the extra work; plus an allowance equal to 25 per cent of the sum of this labor and material cost, which percentage shall be the only amount to be paid in addition to said costs. No claim for equipment rentals, delays, insurance and similar items shall be made or allowed. All such items are embraced in the 25 per cent to be allowed as stated above.

Section 2C-2—Preparation of Surfaces

Shot blasting, sand blasting, power-driven scaling tools, flame cleaning and brush cleaning are methods commonly used for cleaning steel surfaces prior to repainting. The first three are preferred on account of their superior results, particularly in cleaning the rust, corrosion and old paint out of pits.

Sec. 2C-2.1—Brush Cleaning

If the old paint is in good condition, adheres tightly to the steel and is hard and not too thick, it may be left on. All rust, loose mill scale and loose paint shall be removed by means of scalers or scrapers *and* wire brushes (preferably power driven), emery cloth or sandpaper, and either air or cloth dusters. Special care shall be used to clean all pits and roughened areas. In places where blisters or rust has occurred, the steel shall be cleaned until it is bright, either by wire brushes and scrapers or by the use of hand or power sanders. All foreign material, rust and loose paint shall be removed, and any old paint which has been allowed to remain shall have a clean surface and be tight to the steel.

All rust, scale and sediment collected inside of the tank bottom shall be entirely removed from the tank and the inside surfaces swept clean. In cleaning elevated tanks, such rust, scale, etc., shall be lowered to the ground by acceptable means and disposed of in a manner satisfactory to the tank owner.

Sec. 2C-2.2—Shot- or Sand-Blasting

When shot- or sand-blasting equipment is available, or when the condition of the steel is such that the methods described in Sec. 2C-2.1 are incapable of properly cleaning the steel preparatory to painting with red lead (and always in connection with the preparation of the surface for the application of coal-tar enamel coatings or for wax-grease type protection), all surfaces shall be cleaned by shot or sand blasting. The shot- or sand-blasting equipment shall have ample capacity to furnish the required volume of compressed air to operate the blast effectively. The air shall be free of oil or moisture. If sand is used, it shall be principally composed of silica grains and shall be as coarse as it is practicable to use. Provision shall be made to prevent the spreading of sand to adjoining property. Steel grit may be used in lieu of sand at the option of the contractor.

Whatever metal is cleaned by sand blasting *on any day* shall be coated with primer *on the same day*. If rust forms on any sand-blasted surface from any cause, the surface shall be recleaned, as necessary, before the application of primer.

After cleaning, all surfaces shall be wiped free of any dust resulting from such cleaning.

Section 2C-3—Paint

Before any type of primer or paint is applied to the steel surfaces, steps shall be taken, either by the circulation of air or by the application of heat, to dry the metal surface completely.

Sec. 2C-3.1—Kind of Paint *

It is recognized that various types and kinds of paint have in great measure demonstrated their suitability for water works use and that no type or kind is universally applicable. The types of paint which have in general given the best service, and which are believed to represent the best practice at the present time, are: (1) red lead and oil, (2) red lead and synthetic resin, (3) coal-tar enamels and (4) wax grease.

Sec. 2C-3.2—Lead and Oil Paint

For repainting rough surfaces, three-coat work is ordinarily recommended. Two-coat work is satisfactory where surfaces are smooth and full coverage is practicable without "holidays." Only when the old paint is in good condition, except for minor spots which can be touched up satisfactorily, is a single coat acceptable.

Although red lead in linseed oil is still recognized as one of the best protective coatings for steel, its use has largely been superseded by red lead in the more rapid drying water-resistant synthetic resin (phenolic) varnish, which is specified herein for interior use.

3.2.1—Interior Paint

If the interior surfaces have been previously unpainted, or if the old paint has been completely removed and the surfaces have been carefully prepared, a minimum of three coats of paint should be used. Alternate coats of the same paint should be tinted slightly by the addition of a small quantity of lamp black or iron blue in order that full coverage with each application will be assured.

On a previously painted surface where the old paint is generally in good condition except for minor failed areas, these areas should be touched up with two coats of the paint and the entire surface then given a full coat.

All interior surfaces of the tank shall be painted with (or touched up with) paint complying with Federal Specifications of the Bureau of Standards TT-P-86a, Type IV, with all subsequent amendments, if any. The paint shall set to touch in not more than one hour and shall dry through in less than six hours.

Paint shall be delivered to the job in original containers marked with the name of the manufacturer and the type and quantity of materials contained therein.

The paint shall not show excessive settling in a freshly opened full can and shall easily be redispersed with a paddle to a smooth, homogeneous state. The paint shall show no curdling, livering, caking or color separation and shall be free from lumps and skins.

The paint as received shall brush easily, possess good leveling properties and show no running or sagging tendencies when applied at a spreading rate

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* Since it has not been possible to obtain from the Asphalt Institute, the Federal Specifications Board or the American Society for Testing Materials a standard specification for an asphaltic paint, such material is not included in this document.

of 500 sq.ft. per gallon to smooth steel vertical surfaces.

The paint, when reduced with not more than one part by volume of mineral spirits (conforming to Federal Specification TT-T-291a, Grade I) to eight parts of the package material, shall spray satisfactorily, show no tendency to orange-peel, sag, creep or run, and show spraying properties in all other respects.

The paint shall not skin within 48 hours in a three-quarters-filled closed container.

The paint shall dry to a smooth uniform finish, free from roughness, grit, unevenness and other surface imperfections. The paint shall show no streaking or separation when flowed on clean glass.

When exposed to cold distilled water, as specified in Federal Specifications TT-P-86a (Sec. E-5j and F-2b), the film of paint shall show no blistering or wrinkling immediately upon removal of the panel. There shall be no softening of the film and no more than a slight whitening when examined two hours after removal.

3.2.2—Outside Surfaces

Outside surfaces which have been previously unpainted or from which all the old paint has been removed should receive two complete prime coats. The second coat should be altered slightly by the addition of lamp black or iron blue in order that full coverage may be assured. On previously painted surfaces, where the old paint is generally in good condition except for minor spots, these spots should be patch coated with one or two coats of the primer, prior to the application of the finish-coat paints.

The outside prime coat, or the patch coat, shall comply with Federal Specifications TT-P-86a, Type I, which require the use of red lead in linseed oil weighing not less than 24 lb. per gallon.

Paints based on the following specifications have demonstrated their usefulness for outside finish coats:

White—Federal Specifications TT-P-40, Amendment 2, Type I, Class A (white lead-titanium dioxide-zinc oxide-extender-linseed oil)

Tint Base—Federal Specifications TT-P-40, Amendment 2, Type I, Class C (same as Class A, but nonchalking rutile type titanium dioxide specified)

Black—Federal Specifications TT-P-61a (red lead-carbon-extender and/or iron oxide-linseed oil)

Aluminum—Federal Specifications TT-V-81a, Type II, Class B ("Varnish; Mixing for Aluminum Paint") and TT-A-468, Amendment 3, Type II, Paste Grade I, Class A ("Aluminum Pigment: Powder and Paste"); mix 2 lb. of aluminum paste and 1 gal. of aluminum mixing varnish

Foliage Green—State of Maine Highway Dept.; the formula for this paint is as follows:

Finish Coat—Medium Green	Amount
Semipaste white lead	100 lb.
Chrome oxide green paste in oil	20 lb.
Raw linseed oil	3¼ gal.
Varnish	½ gal.
Turpentine or mineral volatile spirits	1 qt.
Yield (approximate)	8¼ gal.

Sec. 2C-3.3—Hot-Applied Coal-Tar Enamel

Such coating material shall meet the requirements of the applicable provisions of A.W.W.A. Standard Specifications for Coal-Tar Enamel Protective Coatings for Steel Water Pipe (7A.5-

1940 and 7A.6–1940). Application must conform exactly to the instructions of the manufacturer of the product used.

Sec. 2C–3.4—Wax-Grease Paint

Wax-grease coatings may be either of the cold-application type or of the type adapted for hot application.

Section 2C–4—Application of Paint

Sec. 2C–4.1—Red Lead and Oil or Red Lead and Synthetic Resin

Red-lead paint may be applied either by spraying or by brushing. If applied by spraying, care shall be taken that suitable nozzles are used and that the air pressure, both on the liquid in the container and on the atomizing nozzle, is within the ranges recommended by the paint and equipment manufacturers to produce good work. If the spray method is used, care shall be taken that no spray falls on near-by structures. Spraying of exterior surfaces shall be confined to quiet days when it will not adversely affect adjacent property. The contractor shall be responsible for any and all damage resulting from spray drifting.

If the paint is applied by brushing, it shall be brushed on in one direction and then smoothed in a direction at right angles, to produce as uniform a thickness of coat and as complete a coverage as possible. (This required two-directional brushing is "one coat" within the meaning of this procedure.)

Care shall be taken to insure the application of a uniform coating carefully worked around rivet heads, joints and other irregularities in the surface.

Each coat shall be allowed to dry thoroughly before the next coat is applied; however, not more than 48 hours shall elapse between successive interior coats of the phenolic type vehicle.

Paint shall be applied only when the air temperature is at or above 40°F. No paint shall be applied during wet or foggy weather, or upon damp surfaces or metals coated by frost.

Sec. 2C–4.2—Coal-Tar Enamels

The detailed recommendations of the manufacturer shall govern the application of coal-tar enamels.

The coal-tar primer shall be evenly applied and care exercised to avoid runs, festoons or other accumulations of heavy primer. No coal-tar primer shall be applied when the steel temperature is below 35°F.

After the coal-tar primer is dry, the surfaces will receive the application of the hot coal-tar enamel. If more than five days have elapsed since the coal-tar primer was applied, the surfaces shall be given a light thinned coat of coal-tar primer and this application allowed to dry.

The coal-tar enamel shall be broken up into small pieces and heated in a suitable melting kettle. A slow flame shall be used for the initial heating before the flame is turned on full force.

When the hot enamel is drawn from the heating kettle, it shall be strained through a fine wire screen to remove all foreign substances.

Immediately before applying the hot coal-tar enamel, the primed surfaces shall be wiped free of any dust or foreign matter.

Sec. 2C–4.3—Wax-Grease Paints—Cold-Application Type

Cold-application type wax-grease paints shall be thoroughly rubbed on to

the clean dry metal with a stubby brush to insure thorough wetting of the metal surface and absorption of all occluded moisture. The coating shall be applied to a thickness of not more than 0.0312 in. and not less than 0.0234 in.

The tank can, if needed, then be put into service as soon as the painting is complete.

Sec. 2C-4.4—Wax-Grease Paints—Hot-Application Type

Because of its physical properties and special method of application, it is recommended that the hot-application type of wax-grease paint be applied only by an experienced painting contractor, who is properly equipped to handle this material.

The material shall be applied to the dry surfaces by means of a spray apparatus, utilizing fluid pressure through special nozzles. Sufficient pressure shall be used to impinge the molten material on the metal surface. The temperature of the coating shall be not less than 250°F. and not more than 300°F. After application to the surface, the coating should be thoroughly flashed or flamed by means of a torch, to smooth out all laps and close any pinholes. The thickness of applied coating shall be not less than 0.0315 in. or more than 0.0625 in.

Section 2C-5—Ventilation

The contractor must provide adequate ventilation while painting the interior surfaces of a tank. This is particularly important where tar products are used. The ventilation shall be adequate to remove fumes and prevent injury to workmen or the possibility of accumulating volatile gases.

Section 2C-6—Cleanliness

The contractor and all workmen employed by him shall conduct all operations in a clean and sanitary manner. No nuisance shall be committed in a tank; the workmen shall either use proper waste receptacles or leave the tank whenever necessity arises.

No one shall work in a tank if he has been under a physician's care, or has needed a physician's care, within a seven-day period prior to entering or working in the tank. No person shall be permitted to work in a tank who has an abnormal temperature or gives evidence of illness. The tank owner, or a physician employed by him, shall be the judge of the physical fitness or unfitness of any person to enter or work in a tank. No deviation from this stipulation may be permitted.

The tank owner, after work of any nature is done in a tank, is charged with satisfying himself that the tank interior is clean and sanitary before the tank is returned to service. Although a contractor may be required by his contract to clean all painted surfaces thoroughly before a tank is restored to service, it is the ultimate responsibility of the tank owner either to give the tank a final field inspection or to require such laboratory tests of the quality of water held (for test purposes) in the tank as will demonstrate the good sanitary condition of the tank interior. (See the note on disinfection procedure at the end of this document.)

Section 2C-7—Inspection

The owner shall inspect the painting as it is being done or employ an inspector to do so. Payment for painting done shall be made only after the owner has satisfied himself directly that the painting is satisfactory; or after an inspector's report has been filed with the owner certifying that the painting has been done properly and in accordance with the terms of the contract.

It is in the mutual interest of the owner and the contractor that such inspection be made promptly.

NOTE

Disinfection Procedure. After inspection, repair or painting has been completed, a tank should be disinfected before it is replaced in service. This should be done following the leakage test and general inspection of the work. If the tank is not used for water service between the repair and painting operations, intermediate disinfection is not necessary.

The tank should be slowly filled to the overflow level with potable water, to which enough chlorine is added to provide a concentration of 50 ppm. Cl in the full tank.

The chlorine, either as high-test calcium hypochlorite (H.T.H., Perchloron or equivalent) or liquid chlorine, should be introduced into the water as early during the refilling operation as possible. A simple and effective method of adding the disinfectant consists of scattering hypochlorite powder over the water surface in the partly filled tank—working from the manhole or entry opening on or near the top of the tank. As the water rises to fill the tank, the chlorine will be dissolved and dispersed so that it will make contact with the metal surfaces. After the tank has been filled, it should stand full for 24 hours, if possible, but for not less than 6 hours. (Disinfection with chlorine at the 50-ppm. rate is practically instantaneous, *if* the polluting material is not protected by films or gross particles. The 6-to-24-hour holding requirement is intended to provide a factor of safety.)

After the holding period, the highly chlorinated water in the tank must be completely drained to waste and the tank refilled from the regular supply. Subsequent to refilling, samples of water should be taken from the tank in order to demonstrate and record the good sanitary condition of the tank, before it is restored to regular service.

The tank owner and the inspector, the repair contractor or the painting contractor shall, prior to any work in the tank, reach a definite understanding concerning the disinfection procedure to be used, and shall assign responsibility for the actual task of disinfection, recording this understanding in the contract.

Abstracts of Water Works Literature

Key: In the reference to the publication in which the abstracted article appears, **39**:473 (May '47) indicates volume 39, page 473, issue dated May 1947. If the publication is paged by the issue, **39**:5:1 (May '47) indicates volume 39, number 5, page 1, issue dated May 1947. Abbreviations following an abstract indicate that it was taken, by permission, from one of the following periodicals: *B.H.—Bulletin of Hygiene* (*British*); *C.A.—Chemical Abstracts; Corr.—Corrosion; I.M.—Institute of Metals* (*British*); *P.H.E.A.—Public Health Engineering Abstracts; S.W.J.—Sewage Works Journal; W.P.R.—Water Pollution Research* (*British*).

CANADIAN WATER SUPPLIES—GENERAL

Water Works Systems [of Canada]. ANON. Wtr. & Sew. (Can.) **85**:8:3 (Aug. '47). Since first municipal works built at Halifax, N.S., in 1848, number has increased to 1309. Over 6,000,000 people served, 55% of total population. Half supplies from ground and half from surface sources. Estimated 12,000 mi. of pipe 4″ or over, average 9′ per person served; 110 services per mi. and slightly more than 4 persons per service. Annual hydrant maintenance averages $4.57 each. Practically all industrial and commercial services metered, and metering of domestic service increasing. Average water rates for 5-room house ($2000 assessment, 4 occupants, frontage 45′) $16 flat and $14.45 metered, yearly. Billing periods: 3 mo., 62%; 2 mo., 17%; 1 mo., 9%. In 80% of cases, fire protection charges based on number of hydrants, ranging from nothing to $200 and averaging $40–50 per hydrant per yr.—equiv. to 47¢ per capita, or $307 per mi. of main.—*R. E. Thompson.*

Administration. ANON. Wtr. & Sew. (Can.) **85**:8:4 (Aug. '47). In Canada, few privately owned water systems. In Ontario, 115 operated by commissions and 162 by councils—in other provinces, except Maritimes, commission administration used less extensively. Joint administration of all sanitary service by 1 commission not widely practiced. Financing usually by debentures which are obligation against all taxpayers. Equal annual installments of principal and interest now used rather than sinking fund payments. Debenture and operating costs met by general taxation based on assessment; frontage tax; service charge; or rates based on service provided. Procedures vary widely.—*R. E. Thompson.*

Chlorination. ANON. Wtr. & Sew. (Can.) **85**:8:8 (Aug. '47). There are 573 chlorination plants in Canada, over 25% of municipal systems being so equipped. In Quebec, 139 chlorination plants; and in Ontario, 259, over 80% of all water supplied in latter being chlorinated. Typhoid death rate has dropped from 50 to less than 1 per 100,000 and in many parts of country it has reached vanishing point. —*R. E. Thompson.*

Water Distribution. ANON. Wtr. & Sew. (Can.) **85**:8:16 (Aug. '47). In Canada, 62% of mains 6″ and 4″ diameter, and 15% 8″. Average prewar cost of 6″ main $2.20 per ft. Average per capita valuation of water works systems, prewar, $47.85. Earth cover over mains 2′–9′, in southern Ontario commonly 5′. Hydrants average 8.5 per mi. of main—spacing in business area 200′–400′, residential 300′–800′. Survey prior to war showed that in 53% of systems percentage of domestic services metered less than 1%. Cost of meter reading 4¢ to $1 per meter per yr.—*R. E. Thompson.*

Water Filtration. ANON. Wtr. & Sew. (Can.) **85**:8:6 (Aug. '47). Filtered water supplied to 3,500,000 people in Canada, or 30% of total population; nearly 60% of population served by public systems. Filter plants number 140—gravity mechanical 83, pressure mechanical 45, slow sand 12. Of these, 114 in Ontario and Quebec. Infiltration systems, first used in 1875 at Hamilton, largely abandoned. Pressure and slow sand plants now seldom installed. Alum used almost exclusively, dry feed being predominantly employed. Mixing effected by spiral flow tanks in 15 plants and mechanical units

in 16. Use of anthrafilt gradually increasing. Wash rates 15″–40″, usually about 24″. Air used extensively only in Quebec. Palmer agitators installed at number of plants. Capital cost for rapid sand plants: per capita, $2.30–$43.10, average **$11.35**; per mil.gal. designed capacity **$23,800–$224,000**, average $68,000; per sq.ft. sand area, average **$159.20**. —*R. E. Thompson.*

Taste Control. ANON. Wtr. & Sew. (Can.) **85**:8:10 (Aug. '47). All usual methods employed in Canada. Survey of activated carbon use showed average dose 4.13 lb. and cost 41¢ per mil.gal. total consumption. Dosage varied from 0.28 to as high as 120 lb. per mil.gal. during period of application. ClO_2 used at number of plants and found effective for taste due to phenols and algae.—*R. E. Thompson.*

Sewage Treatment Standards. R. BOWERING. Wtr. & Sew. (Can.) **86**:6:26 (Jun. '48). Discussion of criteria for determining degree of treatment required and results that may be expected from various types of plants. Chief criterion is dilution afforded by, and use made of, receiving body of water. Standards suggested by Imhoff and Fair for various classes of receiving bodies and Interstate Compact of Connecticut, New York and New Jersey requirements for sewage discharged into tidal waters given, together with approximate efficiencies of various types of plants in terms of removal of suspended solids, B.O.D., and coliform bacteria.—*R. E. Thompson.*

Industrial Waters of Canada. Report of Investigations, 1934–1943. HARALD A. LEVERIN. Can. Bur. of Mines Rept. No. 819 ('47). Revision of Report No. 807, incorporating information contained in Interim Report No. 6. Includes anals. of 930 samples, 278 from surface and 652 from civic water supplies. Anal. methods outlined. Discussion of impurities found in natural waters, their origin and effect on various industrial processes, corrosion, and commonly employed methods of water purification. Hardness of waters examined, discussed fully, with tables and diagrams showing: variation in hardness of Great Lakes water from Port Arthur to tidewater; persons served by supplies of different degree of hardness; weighted (in proportion to population served) average hardness of large public supplies by provinces; and source and treatment of public supplies in cities and towns with population of 3000 and over in eastern Canada and 2000 and over in western Canada. Hardness maps included. Ground waters preponderantly very hard (over 180 ppm.), while surface waters on average hard and medium hard (61–180 ppm.). Water supplies in coastal provinces, in general, soft. Supplies studied serve 52.4% of total population and weighted average hardness for those from surface sources is 97.8, for those from ground sources 343.8 and for all supplies 118. Ground waters serve only 7.6% of population supplied from sources studied. Only 3 municipal softening plants, all base-exchange type.—*R. E. Thompson.*

Well Water Systems. ANON. Wtr. & Sew. (Can.) **85**:8:12 (Aug. '47). Wells used for all or part of supply in 225 Canadian municipalities, 17% possessing public systems. In Ontario 95 such supplies, in Quebec 77 and in Saskatchewan 21. Number of larger municipalities so supplied. Depth varies from 25′ to 500′—usually 100′–150′. Pumping usually by submerged units with electric motors at surface. Considered good practice to remove pumps every 5 yr. for inspection and repair. No indication of recession of water table, levels remaining constant, apart from seasonal fluctuations.—*R. E. Thompson.*

The Columbia Basin Water Resources in Canada. C. E. WEBB. Eng. Jour. (Can.) **30**:601 (Dec. '47). Describes Columbia R. Basin and developed power sites within its boundaries, both in U.S. and Can. Discusses various surveys and investigations currently carried out by Intl. Columbia R. Eng. Board for Intl. Joint Commission. Personnel of board listed and progress to date in each phase of work given. Summary of benefits from these studies accruing to Columbia Basin residents and to all Canada.—*Ed.*

Improvement Program for Halifax Water System. J. D. KLINE. Eng. Cont. Rec. (Can.) **60**:6:82 (June '47). Concrete reservoir, 3.5-mil.gal. capacity, built in '13 repaired by guniting and flat roof replaced by prestressed gunite dome after raising walls 4′. Capacity increased 0.5 mil.gal. New booster station (Dutch Village Rd.) containing three 7-mgd. units constructed on low-service system. Air-elec. automatic control responds to demand in 13 steps, controlled by cam switches. Waste water survey disclosed waste in excess of 5 mgd., prior to which 50% of water unaccounted for. Despite Cu intake

screens of less than ⅛″ mesh, eels gained access to system during low-water period each fall. Electric fish screens consisting of ⅜″ pipe electrodes across intake 2″ center to center and ground approximately 2′ from electrodes on lake bottom, gave complete protection in '46. Eels not killed but diverted from course on entering electric field. Main cleaning practiced since 1875. Self-acting scraper employed in 1880. In '46, 8 mi. of 15″ transmission main cleaned. Capacity increased about 40%.—*R. E. Thompson.*

Dutch Village Road Station, Halifax (N.S.). ANON. Wtr. & Sew. (Can.) **85**:4:23 (Apr. '47). Owing to great differences in elevation, distr. system consists of 2 services—high, supplied by gravity from Spruce Hill Lake; and low, supplied from Chain and Long Lakes, also by gravity until '42 when constant-speed pump installed on 1 of 2 low-service mains. New station, equipped with three 7-mgd. variable-speed motor-driven centrifugal pumps (1 for stand-by), provides pressure boost on entire low-service system as required, controlled by air-electric automatic equip. Pressure increased in case of fire.—*R. E. Thompson.*

Further Extension of Ottawa Water Works May Soon Be Urgently Required. C. T. HEENEY. Wtr. & Sew. (Can.) **84**:12:18 (Dec. '46). Business and other sections at highest city elevation have prevented constr. of reservoirs floating on distr. system, and hence pumping stations and purif. plant must be operated to coincide with demand, necessitating auxiliary pumping equip. to meet max. demand. Plants served by lines from different power sources, and, in event of complete failure, purif. plant supplied by diesel engine driven low-lift pump, head created thereby driving generator which supplies current for chem. feed machines, lights, etc., while load of high-lift pumps taken over by hydraulic turbine driven pumps in Queen St. W. Station. Water in top third of 6-mil.gal. clear well flows by gravity to latter and consequently water el. in clear well maintd. as high as possible. Purif. plant, rated capac. 35 mgd., placed in operation in '32. Outbreak of war brought increased consumption and, to flatten peak, lawn sprinkling permitted in east and west sections of city on alternate evenings only (alternation of hr. tried first). In '42, 3 old (1874–6) turbine-driven reciprocating pumps replaced by turbine-driven centrifugals and constr. by civic forces of 2 new filters commenced, increasing capac. to 42 mgd. During '46, daily pumpage as high as 27.3 mil.gal., with peak demand up to 40, and further extensions will be required if increase continues. —*R. E. Thompson.*

Report on a Revised Plumbing Code for Ontario. A. E. BERRY. Eng. Cont. Rec. (Can.) **61**:1:88 (Jan. '48). Present legislation permits but does not require preparation and enforcement of code by each municipality. Some minimum requirements included in Public Health Act, but these very limited. Act, however, authorizes adoption by order-in-council of regulations for control of plumbing throughout province. Plumbing Code Committee of Ontario Assn. of Plumbing Inspectors and Affiliates, with representatives from all interested groups and associations, has prepared draft code for review and discussion. From this should emerge standard of minimum requirements which could be modified by individual municipalities to provide higher standard if desired. General principles include: (1) provincial examining board, (2) provincial rather than local licensing, (3) continuing advisory committee, (4) laboratory for testing and demonstrating new devices, etc., and (5) provision of trained inspectors by municipalities. **Revising Ontario Plumbing Code.** W. H. RIEHL. Eng. Cont. Rec. (Can.) **61**:1:90 (Jan. '48). Report of representative of Canadian Inst. of Sewage and Sanitation, presenting points in draft code which proved most controversial and those of major interest to those concerned with municipal sanitation. Recommendations include laying of water and sewer pipes in separate trenches, wherever possible at least 5′ apart, except in solid rock; failing this, water pipe should be laid on bench at least 12″ above top of sewer pipe; placing of water outlets to plumbing fixtures above flood level rim of fixture at minimum vertical distance equal to twice diameter of effective opening of water supply discharge; and minimum diameter of 1¼″ for ferrous pipe and fittings used underground, all such threaded pipe and fittings to be zinc-galvanized or cement-lined.—*R. E. Thompson.*

Dual Water Supply System at South Porcupine, Ont., to Be Unified. ANON. Wtr. & Sew. (Can.) **86**:1:22 (Jan. '48). At present, domestic supply pumped from springs through 6″ steel main to 35,000-gal. standpipe and thence by gravity to distribution system. Fire protection supply pumped directly from Lake Porcupine into mains serving hydrants. Unification program includes deep well,

500,000-gal. reinforced concrete reservoir and 12″ cast-iron supply main 20,000′ long. Gravel-wall well has capacity of 600 gpm., is 45′ deep, 26″ in diameter, and has 14″ inner casing and screen. Water hardness 135 ppm., Fe zero and temp. 41°F. Consumption about 55 gpd. per capita.—*R. E. Thompson.*

Toronto's New Filtration Plant Reduces Chemical Costs. Norman J. Howard. Wtr. & Sew. (Can.) **85**:2:18 (Feb. '47). Water supply drawn from Lake Ontario through 3 intakes, 2 feeding Island plant and other R. C. Harris (formerly Victoria Park) plant placed in commission Nov. '41. Best raw water available for treatment selected on basis of lab. tests at 2–3-hr. intervals. Taste tests made every 30 min. Water treated increased from 73 mgd. in '40 to 92.5 in '46. On basis of chem. costs in '40, last year Island plant supplied entire city, savings in 5-yr. period, '42–'46, were: alum $1300, Cl $54,760, SO_2 $53,915; total $109,975, almost sufficient to maint. labs. at both plants for 4-yr. period. In addn., city water quality improved and danger of shortage elimd. Results have justified selection of site for new plant.—*R. E. Thompson.*

Canada's First Watersphere. E. N. Zimmerman. Eng. Cont. Rec. (Can.) **61**:7:82 (July '48). Watersphere at Port Union, Ont., plant of Johns-Manville Co., has capacity of 100,000 gal. Supporting cylinder, also serving as riser, 6′2″ to 8′ diameter, resting on cone-frustum base 18′ high and flaring to 29′4″ diameter at bottom. Overall height 127′. Sphere 30′ in diam. Total weight of steel 63 tons. Butt-welded **V**-joints throughout. Painted with 1 coat red-lead primer and 2 coats Al.—*R. E. Thompson.*

Add Sixteen Rapid Sand Filters to Montreal Plant. H. A. Gibeau. Eng. Cont. Rec. (Can.) **60**:4:74 (Apr. '47). Present plant, rated capac. 150 mgd., supplies avg. of 155 and up to 179 mgd. for long periods, despite increased raw water poln. To relieve overloading, capac. being increased to 200 mgd. by constr. of fourth battery of 16 filters. Below filters will be 2 filtered water basins, 230′ × 50′ and 16′ deep. Approx. 36,000′ of 36″ and 48″ steel mains laid '07–'14 reconditioned last yr. at cost of $244,000. Length about 7′ cut from section to be cleaned, plunger-type cleaning machine equipped with steel scrapers inserted, and length temporarily jointed into place. Machine driven forward under relatively low head of water, material discharged and machine removed from similar opening downstream. Usually, operation repeated before centrifugally placing cement-mortar lining varying in thickness from $\frac{3}{8}$″ to more than $\frac{1}{2}$″ with tolerance of $\frac{1}{16}$″. After curing, inspection and testing for leakage, section chlorinated and returned to service. McTavish reservoir, built 1856 and modified in 1873, being rebuilt and covered at cost of about $1,500,000. Structure will consist of 6 cells with total capac. 35 mil.gal., and top will be landscaped.—*R. E. Thompson.*

Canada's First Welded Elevated Tank for Municipal Water Service. Anon. Wtr. & Sew. (Can.) **85**:12:23 (Dec. '47). New all-welded tank at Sillery, residential suburb of Quebec City, has 300,000-gal. capacity and is supported on 8 cylindrical columns without lateral support, fabricated from $\frac{1}{4}$″ steel plates rolled to 42″ diameter. Tank 51′ in diameter, with ellipsoidal bottom and roof, depth of bottom being $\frac{1}{3}$ and of roof $\frac{1}{4}$ of tank diameter. Central riser, 6′ in diameter, extends 85′ from ground level to tank bottom. Supply from St. Lawrence River by electric-driven pumps, 750,000-gpd. total capacity, operating against head of 210 psi. There are 1000 domestic consumers and consumption averages 500,000 gpd. Pressure maintained between 30 and 55 psi. Head range in tank 26′.—*R. E. Thompson.*

New Pumping Equipment for Sherbrooke (Que.) Water Works. Anon. Eng. Cont. Rec. (Can.) **60**:3:84 (Mar. '47). Avg. daily consumption by 42,000 pop. 6.6 mgd. in '46. Supply from Magog R., chlorinated at 8.5 lb./mil.gal. System includes 2 reservoirs, 10- and 6-mil.gal. capac. resp., and new 2-mil.gal. reservoir contemplated. Till '27, when first motor-driven centrifugal pump installed, reciprocating piston "Triplex" pumps driven by water wheels used exclusively, one of which, now 68 yr. old, employed as stand-by since second centrifugal added last yr. Flow from reservoirs by gravity, but hilly terrain necessitates strategically located booster stations. Pressure at highest point on system increased from 10 to 86 psi., that at lowest point being 127 psi. Chem. anal., in ppm.: $CaCO_3$ 43.5, $CaSO_4$ 10.8, $MgSO_4$ 16.3, oxides 9.6, incrusting solids 80.4, Na_2SO_4 6.2, NaCl 6.2, org. matter 15.4, nonincrusting solids 27.8, total solids 107.9. Free CO_2 and D.O. 3 and 8 ppm., resp., and pH 7.3.—*R. E. Thompson.*

CORROSION

Is Cast Iron Superior in Corrosion Resistance to Steel? R. W. White. Materials & Methods, **26**:2:82 (Aug. '47). In order to determine comparative corrosion resistance of cast iron and steel, bare metals and varnish- and enamel-coated metals exposed to following test conditions: salt fog spray, water vapor, sulfur dioxide fumes, and ultraviolet light combined with periodic water spray. Rusting of uncoated machined samples of iron and steel found to be practically identical while shot-blasted, uncoated cast iron showed greater corrosion due to increased surface area. Corrosion resistance of coated steel found superior to that of coated iron. Graph and various tables included.—*Corr.*

Effect of Sulfur Bacteria on Corrosion. L. Liberthson. Iron & Steel Engr., **24**:6:69 (June '47). Phenomenon of bacterial deterioration of cutting oil emulsions used as illustrative link to indicate why and how sulfur-reducing bacteria may well be regarded as subject for study by industrial microbiologist. Literature briefly surveyed in order to (1) emphasize intersection between lines of investigation familiar to iron and steel technologist and lines normally regarded as primarily biological; and (2) to underline research trends and possibilities in field of corrosion of iron and steel in area where it overlaps existing knowledge of chemo-autotrophic microorganisms.—*Corr.*

Mechanism of Corrosion of Water Pipe. Thomas M. Riddick. Wtr. & Sew. Wks. **94**:R149 (July '47). Discusses above mechanism and presents 3 empirical formulas derived to express numerically corrosive tendencies of water from analyses. Illustrated by photographs of corroded pipes, etc. —*Corr.*

Corrosion Surveys. M. E. Parker Jr. Petroleum Engr. **18**:10:270 (July '47). Major types of surveys in relation to corrosion control of pipelines and their principal functions described. Following discussed: (1) preliminary or exploratory survey, (2) electrical survey of line already laid and (3) survey of line that has been placed under protection. Other special surveys such as determining suitable sites for anode beds considered. Quantities to be measured and various instruments used discussed. Method of recording data presented.—*Corr.*

Long-Term Natural Corrosion Tests on Different Structural Steels in the Atmosphere and in Sea and River Waters. Report I, H. Baudot; Report II, G. Chaudron. Rev. Mét. (Fr.) **43**:1/2:1 (Jan.–Feb. '46). First 2 reports on comprehensive series of tests covering wide range of structural steels (unprotected) exposed at 11 different stations since '38. Report I describes preparation of specimens and test stands. Report II gives analysis of results and comparison with laboratory tests.—*Corr.*

Half Cell for Measuring Corrosion Potentials. J. M. Standring. Elec. World, **127**:3:182 (Jan. 18, '47). Homemade half cell, for measuring potential on underground structures to ground, using telephone receiver shell for housing, wood plug for earth contact, described and illustrated.—*Corr.*

Method for Measuring the Corrosion of Welded Joints. L. I. Frumin. Factory Lab. (U.S.S.R.), **13**:693 (June '47). After short review of types of corrosion taking place in above and their causes, 3 methods of determining amount of corrosion described. These are: use of profilometer (for deep-penetrating corrosion); differential weight method; and application of stress to joints immersed in concentrated alkali.—*Corr.*

Corrosion Coupons and Pipe Life Predictions—Revision of 1947. W. R. Schneider. Corrosion, **3**:209 ('47). Pipeline corrosion rate measurement and pipe life prediction by buried coupon technique comprehensively described. Coupons, $3'' \times 6'' \times \frac{5}{16}''$ cleaned steel plates, buried in pairs near bottom of pipe. One of coupons electrically connected to pipe and acted on by stray and long-line currents as well as by soil; other coupon control, subject to soil action only. Coupons removed yearly, preferably in fall, and corrosion, particularly pit depth, measured. Mathematics of accurately estimating cumulative pit depth from yearly measurements of individual pits given in full detail. Method can be successfully applied to old lines in absence of previous data. Some remarkable instances of accurate pipe life predictions

detection of corrosion conditions, and detection of changes in soil corrosivity from various causes cited.—*Corr.*

Electrolytic Resistance as a Means of Evaluating the Protective Merit of Underwater Organic Coatings on Metals. R. C. Bacon, J. J. Smith & F. M. Rugg. ACS 11th Meeting, Atlantic City (Apr. 14–18, '47). Electrolytic resistance technique for evaluating underwater organic coatings, generally in ⅓ time required for usual exposure test. Proved reliable in more than 300 test systems. In course of this work, wide variety of factors which affect protection offered by submerged coatings on mild steel substrate considered. Effects on protective performance due (1) to differences in pigment, pigment content, and organic binder, (2) to presence of "wash primer" applied to steel substrate prior to application of primer coating, and (3) to variations in sodium chloride and oxygen concentrations in environment have readily been revealed by log resistance time curves. With coatings offering good protection, alternate increases and decreases in high resistance region frequently observed throughout course of test immersion period. Phenomenon believed to be related to formation of corrosion product barriers at or near metal surface.—*Corr.*

Water Immersion of Metal Protective Paints; Role of Electro-Endosmosis in Water Absorption and Blistering. W. W. Kittelberger & A. C. Elm. Ind. Eng. Chem. **39**:876 (July '47). Data presented show that over 90% of total water absorbed by linseed oil type of paint coating, under influence of both concentration and potential gradient, is transferred into film by electro-endosmotic forces. Possibility exists that greater resistance to water absorption and to blistering of some paint coatings is not so much due to greater inherent waterproofness as to appreciably higher electrolytic resistance.—*Corr.*

Galvanic Protection of Iron by Magnesium Anodes. Bernard J. C. Raclot. Métaux & Corrosion (Fr.) **22**:28 (Feb. '47). Properties of both zinc and magnesium considered and pure magnesium found to have highest potential. Anode buried in mixture of tar and paraffin within few feet of pipe.—*Corr.*

Cathodic Corrosion Protection. Anon. Steel, **121**:19:106 (Nov. 10, '47). Essentially, cathodic protection means that structure to be protected serves as cathode of battery. This battery set up by placing metal anodes in soil near buried structure and connecting these with wire; earth acts as electrolyte. Magnesium anodes, made of metal or alloy higher in electromotive series than metal to be protected, considered valuable because of their high driving voltage. By reversing current flow, metal prevents weakening of structure by corrosion. In so-called packaged anode described, anode and lead wire placed in cloth bag containing chemical required for mud, bag placed in ground, and ire connected to cathode, water being poured over anode to give chemicals moisture needed to form chemical mud. Such magnesium anodes, applicable for protection of pipelines, cable, storage tanks, sheet piling, lead sheath cable, steel poles and tower footings, expected to produce cheaper installation and greater ease of maintenance.—*Corr.*

Use of Magnesium, Zinc, Aluminum and Their Alloys in the Cathodic Protection of Steel in Salt Water. R. R. Rogers & C. E. Viens. Can. Metals Met. Inds., **10**:9:18 (Sept. '47). Laboratories of Dept. of Public Works, Ottawa, Can., consulted regarding methods of combatting corrosion of steel piling in sea water. Three series of cathodic protection experiments performed: (1) experiments with cylindrical cathodes; (2) experiments with long strip cathodes; (3) intermittent immersion experiments. Cathodic protection of steel in synthetic sea water quite successful in small-scale experiments described. It is felt that pilot-scale tests in actual sea water would be justified. In selecting anode materials for these larger-scale tests, magnesium or high-magnesium alloys should be considered first where protection of utmost importance and anode corrosion rate secondary. If it is important to have comparatively low anode corrosion rate, even though protection may not be of so high an order, pure zinc or 20–80 magnesium-zinc alloy would appear to be most desirable. It should be pointed out that aluminum may be more successful as anode material in other types of solution. Also, there may be aluminum alloys outside range of compositions investigated in this work which will give good protection in salt water. When backfills and packaging have been studied more fully, anodic protection picture may change considerably.—*Corr.*

Paints as Moisture Barriers. A. C. Elm. Official Digest Federation Paint & Varnish Production Clubs **267**:197 ('47). Water absorption of paint film in solutions of varying osmotic pressures studied. Blistering also followed. Curves in which percentage of water absorption, degree of swelling and blistering are plotted against time are similar. In electro-endosmotic cells, paint films all shown to be charged.—*Corr.*

Antifouling and Anticorrosive Paints Used by the German Navy. C. A. Hopkins & H. A. Ingram. Off. Pub. Board, Rept. PB 38,186 ('45). Discussion of most recent developments in underwater paints used by German navy. Formulas and methods of application included. Special report on German Marine Laboratory at Cuxhaven included.—*Corr.*

Process That Provides Long-Term Protection for Ferrous Metals. Machinery, **53**:12:170 (Aug. '47). Anticorrosive process known as "Zincilate," claimed to provide 20 years of protection to ferrous metals against all common types of corrosive action, described. Coating possesses high abrasion resistance. Even when sizable areas destroyed by unusual scraping or wear, lasting protection said to be assured through cathodic sacrifice of film. Zincilate unaffected by 1000-hr. exposure in standard salt fog corrosion equipment, as approved by A.S.T.M. It has been used successfully on pipelines; interiors and exteriors of water and gasoline tanks; bridges; machine parts; and marine installations, where it affords not only anticorrosive but also antifouling protection.—*Corr.*

Bituminous Coatings for the Protection of Iron and Steel Against Corrosion. Rev. Current Lit. Paint, Colour, Varnish and Allied Inds. (Br.), **116**:128 (Mar.–Apr. '47). Describes bituminous paints classified as (1) wholly bituminous base media, (2) modified bituminous base media, (3) pigmented and filled compositions. Valuable information relating to use of resins, etc., provided, and, among pigments, comminuted metals discussed. Physical properties of bituminous coatings and some general aspects of antifouling program discussed.—*Corr.*

Steam Turbine Blade Deposits. F. G. Straub. Univ. of Ill. Bul. **43**:39:1 (June 1, '46). Summary of studies to determine causes of steam turbine blade deposits. Types of deposits classified, study of solubility of salts in high-pressure steam reported, and tests described which showed that silica distills off from boiler water in appreciable amounts above 660 psi. Proposed that silica concentration in boiler water in higher-pressure boilers should be held below 10 ppm. Method for determining small amounts of silica in steam also described.—*Corr.*

Concept of the Hydrogen Potential in Steam-Metal Reactions. Carl A. Zapffe. Am. Soc. for Metals Preprint No. 15, 38 pp. Thermodynamic study of numerous reactions of metals and alloys with moisture resulted in development of concept of "hydrogen potential." These potentials provide basis for calculating liability of various metal systems to hydrogen pick-up from moisture reaction. Calculations for iron, steel, stainless steel, nickel, chromium, manganese, silicon, aluminum and magnesium shown graphically. Conditions over wide range of temperature, and wide range of humidity and steam pressure, yield calculations which readily explain numerous metallurgical phenomena.—*Corr.*

Silica Deposits in Steam Turbines From Softening of Make-up Through Natural Zeolite. F. R. Owens. Combustion, **19**:1:37 (July '47). Data from number of plants show increase in silica content of water in passing through softener employing green sand. Seasonal increase of silica content also noted. Curves included showing turbine performance prior to and after by-passing green sand softeners. Blasting with fly ash proved much more effective in removing turbine deposits than washing, even over prolonged washing periods. Confirms theory that presence of silica in steam is selective.—*Corr.*

Cavitation in Water Turbines. Joseph Bronner. Wtr. & Wtr. Eng. (Br.) **50**:484 (Oct. '47). Formation of vacuum brought about by evap. of water if pressure sufficiently low. Proper functioning of turbine therefore impossible and corrosion defects set in. Dissolved gases set free at low pressure and rise in bubbles. Assumption that subpressure (in turbine suction line) equal to static suction head correct only for closed guide apparatus with draft tube filled with water. If draft tube of cylindrical shape, water must maint. its veloc. and stored kinetic energy is lost. Endeavor made, therefore, to discharge

water slowly by gradually increasing cross-section area of draft tube in direction of flow. According to law of energy, ignoring friction losses, sum of pressure energy and kinetic energy remains const. (Author shows by computation, under assumed practical conditions, that pressure underneath runner may become less than zero.) Disturbances must, however, be considered, with consequent drop in efficiency, so that neg. value cannot occur. At high speeds with short vanes serious difficulties arise due to cavitation. Kaplan turbines run well at low heads but may fail under higher ones. Remedy lies in enlargement of vane areas, which means going back to older types. Pressures on back face of short vane are lower than behind runner. Experienced engr. can easily identify those places where corrosion often starts. Through lengthening of vanes, "channels" again created, thereby approaching old type of wheels; local subpressures disappear, permissible cavitation coefficient (σ) values become smaller; and danger of cavitation disappears. Local subpressures become considerable with small vanes and increase with diminishing areas at constant full load. In practice it would be difficult, especially with older and complicated types of Francis turbines, to take into acct. all factors contributing to subpressures.—*H. E. Babbitt.*

Protection of Interior of Steam Condensers. Munitions Supply Labs. Paint Notes, **2**:2:52 ('47). Results given of tests on various painting systems used for protecting interior of steam condensers. Best results given by system consisting of 1 coat of alkyd-based red-lead primer and 2 coats of aluminum-pigmented spar varnish.—*Corr.*

Ice Rink Piping Fails During Wartime Shutdown. P. S. PARK. Heating, Piping & Air Conditioning **19**:4:97 (Apr. '47). From visual inspection of failed piping evident that corrosion had progressed from inside to outside of coils. Chemical analysis of corrosion products revealed substantial proportion of chlorides and calcium oxide indicating conclusively that breakdown of calcium chloride brine in presence of air and moisture had occurred, setting up acid condition. During skating season, pH of brine solution should be maintained in 8.0 to 9.0 range, with 8.5 being desirable minimum. As added protection, use of chromate type of treatment suggested, involving chromate compounds which act as corrosion inhibitors through formation of stable, adherent, and nonporous film on surface of metal. During nonoperating season, brine system should be kept full of alkaline brine with periodic tests being made at frequent intervals to ascertain pH of solution. —*Corr.*

Relative Effectiveness of Cathodic Protection and Painting in Preventing the Corrosion of the Interior of Steel Tanks. T. W. HISLOP JR. Am. Ry. Eng. Assn. Bul. **462**: 196 (Nov. '46). Progress report showing how cathodic protection may be applied to tanks. So far, it has proved more effective than paints.—*Corr.*

Galvanic Aluminum Anodes for Cathodic Protection. R. B. HOXENG, E. D. VERINK & R. H. BROWN. Corrosion **3**: 6: 263 (June '47). Lab. and service data indicate that tech. development of galvanic aluminum anodes in wet and packaged backfills has been successfully directed towards (1) increasing anode-to-soil potential, (2) decreasing anode-to-soil resistance, (3) increasing amp-hr. per pound. At present stage of development it is believed that aluminum anodes will give at least 675 amp-hr. per pound in properly prepd. packaged or wet backfills. At 675 amp-hr. per pound, 1 lb. of aluminum does work of 1.12 lb. of magnesium or 2 lb. of zinc. Relative metal cost per amp-yr. for aluminum, magnesium, and zinc, based on currently quoted anode prices in carload lots, is as follows:

Metal	Estd. amp-hr./lb.	lb./amp-yr.	Price Factor
Al	675	13.0	1.00
Mg	600	14.7	1.62
Zn	335	26.2	1.81

On this basis, apparent that light metals can supply current more economically than zinc. Obviously, in addn. to metal cost, installation costs must be included in detg. total cost per amp-yr. By using packaged anodes, substantially reduced installation costs anticipated. Development work now in hand gives promise of more amp-hr. per pound and of improved packaging techniques, hence not unreasonable to expect further improvement in cathodic protection by using galvanic aluminum anodes.—*Corr.*

Erosion [of Pump Impeller] Proved by Laboratory Test. GLEN H. INGELS. Southern Power and Ind. **64**: 6: 61 ('46). Chem. anal. and metallographic examn. of worn bronze

pump impeller showed that metal substantially unchanged; this fact indicated that wear due to erosion rather than corrosion. Soln. of problem: elim. foreign matter from water, use harder alloy impeller, or reduce speed of pump.—*I.M.*

Cathodic Protection of Pipelines [Use of Magnesium Anodes]. H. SEYMOUR. Mining Mag. **76**: 6: 339 ('47). Corrosion of metal surfaces in presence of moisture for most part electrolytic, and may be greatly reduced or prevented entirely by use of expendable and replaceable anode. Proper alloy compn. of anode and suitable backfill surrounding it essential to elec. eff., while c.d. important factor. Specification range of suitable magnesium alloys is: aluminum 5.3–6.7, manganese (min.) 0.18, zinc 2.15–3.5, silicon (max.) 0.3, copper (max.) 0–0.5, nickel (max.) 0.003, iron (max.) 0.003, other impurities (max.) 0.3%, magnesium remainder. Review of value of magnesium in cathodic installations given. —*I.M.*

HEALTH AND HYGIENE

Bilharziasis in the Gezira Irrigated Area of the Sudan. R. W. STEPHENSON. Trans. Roy. Soc. Trop. Med. Hyg. (Br.) **40**:479 (Mar. '47). Both forms of bilharziasis, *S. haematobium* and *S. mansoni*, are endemic throughout most of Sudan. Irrigation system in Sudan includes 2600 mi. of canals and covers 850,000 acres. There are about 349,000 people in southern district and some 170,000 in northern district. Yearly influx of migratory workers during cotton picking season. Number of measures used to prevent bilharziasis from becoming endemic were discussed. Investigations were made to determine present conditions. Incidence of *S. haematobium* was high throughout area, and infection rate among children was much greater than among adults. Infection due to *S. mansoni* was widespread. Canals were found to be heavily infected with bilharziasis snail. Control of disease was attempted by disinfecting the canal. To date all control measures have failed. It is believed that reduction in snail population and control of growth of weeds in canals will aid in reducing incidence of disease. Other control measures discussed.—*P.H.E.A.*

Infectious Hepatitis. Report of an Outbreak, Apparently Water-Borne. F. F. HARRISON. Arch. Internal Med. **79**:6:622 (June '47). As in poliomyelitis, there are various schools of thought as to what is common mode of spread of infectious hepatitis. Virus has been detected in feces, urine and blood only, and not in naso-pharyngeal secretions, so that view that intestinal-oral route is responsible is favored by many. Although there have been small outbreaks of infectious hepatitis in which attempt has been made to incriminate milk, there has been no clear-cut evidence of milk-borne or food-borne epidemics. In recent years, however, there have been number of instances in which infected well water could be incriminated on epidemiological grounds; and Neefe and Stokes were able to obtain strong evidence that etiological agent of infectious hepatitis was present in particular incriminated well by giving water from it to human volunteers. Incident described by present author is good example of probable water-borne infection, as deduced solely on epidemiological grounds. Battalion in Italy in '45 was in action on series of ridges where it dug in. There were 4 companies A, B, C and D, and headquarters unit. Companies A, B and C separated, with C in center and members of D company divided among them. Headquarters unit and C company used common well. A and B companies each had own well and members used that at headquarters only when on duty in area. First cases of hepatitis occurred on Mar. 27, 24 days after battalion moved into this area, and there were 100 cases of hepatitis with jaundice under treatment in hospital on May 1. Strength of various units not given, but cases distributed as follows: C company, 55; headquarters, 20; B company, 12; D company, 12; and A company, 1. About 75 of 100 patients in this series were interviewed, and only 1 (other than man from A company) claimed to have had no water from well serving C company and headquarters. Except for well water, no essential difference found between conditions experienced by A and C. Some men who had drunk as little as 2 canteens of water became jaundiced. Well was of loose stone type of construction, and there was abundant evidence of fecal contamination of ground immediately uphill from it. Water found to be heavily con-

taminated with coliform organisms, but no pathogens isolated. Italian family living at farm had been there for 22 years and claimed to have been free from jaundice.—*B.H.*

Nitrate Levels in Water From Rural Iowa Wells. A Preliminary Report. GARTH JOHNSON ET AL. J. Iowa State Med. Soc. **36**:4 ('46). Data from nitrate detns. of series of privately owned wells in Iowa recorded. Significant number of wells found to contain nitrate in amt. demonstrated to produce cyanosis in infants. Of 243 dug wells tested during first 6 months of '45, nitrate-N content exceeded 20 and 50 mg./l. in 28.9 and 15.3% of cases, resp.; in one instance nitrate-N content over 500 mg./l. Implication clear that hazard to infant health exists in rural areas of Iowa. Precise cause of high nitrate concns. in wells sampled in this study unknown.—*C.A.*

Methemoglobinemia From Nitrates in Well Water. FREDERICK J. CHAPIN. J. Mich. State Med. Soc. **46**:938 ('47). Marked methemoglobinemia appeared in 4-weeks-old infant about 20 hr. after ingestion of formula made with boiled well water containing N as nitrates, 243.5; chlorides, 200; and bicarbonate as $CaCO_3$, 339 ppm. Water was not contaminated. Methylene blue therapy gave excellent results.—*C.A.*

Poliomyelitis: Study of an Epidemic of Forty Cases, Key West, Florida (May–August 1946). Part I. WILLIAM D. DAVIS & CHARLES M. SILVERSTEIN. U.S. Naval Med. Bul. **47**:910 (Sept.–Oct. '47). This article presents detailed account of epidemic, thoroughly discussing: (1) epidemiology, (2) epidemiological history, (3) incubation period, (4) predisposing factors and (5) clinical observations. Modes of transmission considered were: direct contact, water, milk, food, flies and sewage pollution. Water was piped from Florida City and chlorinated three or four times before use, and several hundred cisterns still in use have cross connections with pipelines. Milk, tested regularly, was supplied by two dairies near Miami. Garbage disposal was poor. Cans overflowed, lids fit improperly, and burial of garbage on near-by island was futile attempt because of swampy conditions. Numerous domestic animals kept in city encouraged fly breeding. Main method of sewage disposal was by cesspool and septic tanks, and sewage from 30% of homes was pumped through city lines into ocean near public bathing beaches, where gross pollution often could be observed near shore. Factors incriminated, in order of importance, were: (1) repeated "direct contact"—18 cases of 40 had mingled in groups and with residents of Miami, where epidemic reached its peak when Key West epidemic began; (2) swimming at polluted beaches—8 cases of 40 swam there 2–3 wk. before onset; (3) garbage disposal and flies—at homes of 15 cases of group of 24, conditions were bad on premises or next door. Spraying city of Key West with DDT and chlorinating sewage from city lines commenced at start of epidemic.—*P.H.E.A.*

Epidemiological Studies on Typhoid in Venezuela. DARIO CURIEL & RICARDO ARCHILA, with collaboration of J. A. JOVE & OFELIA ITURBE. XII Conferencia Sanitaria Panamericana. Cuadernos Amarillos. Publicaciones de la Comision Organizadora, No. 5 ('46). This booklet of 176 pages published by organizing committee of 12th Pan-American Sanitary Conference. It deals with 3 outbreaks of typhoid fever in Venezuela, and thorough investigation made in each epidemic is exemplified by profusion of statistics, graphs and maps which are to be found on nearly every page. First and longest article is study of epidemic of typhoid in Altagracia de Orituco, Guárico State, during Mar.–May '41. After general description of this town of 3395 inhabitants, authors deal at considerable length with water supply, which is derived from Orituco R. either directly or indirectly. There are 3 main methods by which inhabitants obtain their water. One system of distribution is by aqueduct. Here river water passes through rudimentary filter, composed of stones and rock, situated in river bank, and is led to unlined well, about $1\frac{1}{2}$ m. deep. When well full, water pumped up to tank, from which it is distributed to about $\frac{1}{3}$ of population in galvanized iron pipes. Neither well nor filter have any protection from possible pollution. Next source of supply is from basins, which are pits constructed in sand a few meters from river, into which water filters from main stream; water carried away in containers. About half population obtains its water by this method. Remainder use river directly or have private wells. Bacteriological examination of samples from all sources indicated very heavy contamination. For example, examination of water in aqueduct showed coliform count of 240,000 per 100 ml. of water, with 4800

colonies per ml. On Mar. 20, '41, because filter gallery required repair, trench dug from river to well. Land traversed by this trench grossly contaminated, as many of neighboring inhabitants accustomed to urinate and defecate on garbage in vicinity. Epidemic began early in Apr. '41 and subsided toward end of May. In all, 78 cases were reported and there were 5 deaths. Before May 9 all diagnoses made on clinical grounds alone. Explosive nature of epidemic suggested water-borne infection and spot map of town showed that most cases occurred along route of distribution of aqueduct. Women affected more than men and greatest number of infections occurred in those between 10–14 years of age. Examination of possible factors in causation of epidemic eliminated milk, ices, shellfish, vegetables and flies. It was decided that water from aqueduct was reponsible, most important arguments being that: of total 78 patients, 66 drank from aqueduct alone or in combination with another source; of 46 patients who drank from only one source, 40 used aqueduct; geographical distribution of epidemic corresponded largely with area of town served by aqueduct; and aqueduct theory explained explosive nature of epidemic and also accounted for fact that less immune children suffered more severely than adults. Next article deals with epidemic in Mérida, town of 15,846 inhabitants. This town receives its water supply by aqueduct from Albarregas R., 98% of houses being thus served. Water supply normally chlorinated. In '44, there were 36 cases of typhoid and paratyphoid, with 6 deaths. In Dec. '44 there was 1 case, but in Jan. '45 there were 213. Incidence dropped to 27 in Feb. and 2 in Mar. There were 17 deaths in all. Clinical aspects of epidemic showed little variance from textbook descriptions and disease was spread uniformly throughout town. Owing to lack of materials, chlorination of town's water supply ceased on Dec. 22, '44, and for 22 days water remained unchlorinated until fresh quantity of chlorine gas arrived on Jan. 13, '45. First cases appeared on Jan. 1. Having eliminated milk, ices, food and flies as possible vehicles of infection, public health authorities decided that water supply was responsible for outbreak. Public advised to boil water and mass inoculation was introduced; these methods, together with reintroduction of chlorination, stamped out epidemic. Lastly come "Some Notes on the Epidemiology of Typhoid Fever in the Libertador Department of the Federal District." This area has pop. of 240,782 persons. In Mar. '40, both number of cases of typhoid and deaths from typhoid began to rise rapidly. This rise continued more gradually through April, after which there was rapid fall. There were 68 cases and 16 deaths during this period. Exhaustive examination of all possible sources of infection led to conclusion that water supply responsible.—*B.H.*

The Family and Dental Disease. V. Caries Experience Among Parents and Offspring Exposed to Drinking Water Containing Fluoride. H. Klein. U.S. Pub. Health Repts. **62**:35:1247 (Aug. 29, '47). Number of towns in southwestern New Jersey were, until '27, supplied with domestic water which was probably fluorine-free. Supply has since then been obtained from deep wells, and it has fluorine content ranging from 1.3 to 2.2 ppm. Children born in area, and not older than 19 years at time of this investigation, exposed to fluorine-containing water all their lives, while their parents, aged 30 years or more, were not exposed to fluorine-containing water during at least first 10 years of life. In this area, 123 fathers and 131 mothers were dentally examined and divided into 3 dental caries susceptibility groups—low, medium and high, based on the number of DMF teeth (DMF: decayed, missing and filled). It was found that children of low DMF fathers had at 10 years of age about 0.5 DMF teeth on average, whereas children of high DMF fathers had about 1 DMF on average at that age. At 16 years of age, children of low DMF fathers averaged rather more than 2 DMF teeth, and children of high DMF fathers averaged nearly 4 DMF teeth. Similar relationship in susceptibility to caries shown between children and their mothers. Author concludes that while exposure to fluorine reduces strength of caries attack, it is not sufficiently powerful to obscure influence of familial factor.—*B. H.*

Mass Control of Dental Caries Through the Use of Domestic Water Supplies Containing Fluorine. F. S. McKay. Am. J. Pub. Health. **38**:828 (June '48). Recent (June '47) authoritative source (J. Am. Dent. Assn.) predicted: "It is estimated that . . . the 3,400,000 children born in 1946 . . . at 16 yr. of age will [each] require 7 fillings and 2 extractions and that 40% of those reaching 40 yr. of age will require dentures." However, evidence has indicated that continuous use of fluorinated water during period of

tooth calcification will produce mass reduction in dental decay rate. Such evidence has been derived almost entirely from examinations of children. Present study based on examination during past 3 yr. of adults who lived continuously in Colorado Springs, Colo., where public water supply in use for 70 yr. contains 2.6 ppm. fluorides. Results compared with similar study at Madison, Wis., where water supply contains 0.05 ppm. fluorides. In 15–19-yr. age group, Madison had 7 times as much decay experience and 22 times as many extracted teeth per person as Colorado Springs; in group of persons 40 yr. and older, Madison had 3 times decay experience and 32 times as many extracted teeth per person as same age group in Colorado Springs. Fluorosis in Colorado Springs classified as "mild." Additional data included show that among migratory workers with fluorosis decay and tooth loss rates are similar to those in Colorado Springs. This suggests that inhibitory effect of fluorides once acquired is permanent and not diminished by later migrations to areas where little or no fluorides found in water supplies.—*F. J. Maier.*

Public Health Aspects of Flood Relief. T. W. Marsden. J. Roy. Sanit. Inst. (Br.) **67**:568 (Nov. '47). General discussion of public health problems which are always present during floods. Quality of water supply is immediate problem during such an emergency. Author reviews efforts made to maintain safe water. Daily samples were taken for bacteriological examination, and determinations of residual chlorine were made on water collected at tap in laboratory. Modified standard of 0.2 ppm. free residual chlorine was maintained. There were no cases of typhoid fever during this emergency, although 6 cases were reported during previous 10 yr. Sewage problem was somewhat difficult one owing to heavy loads at sewage treatment plant, and there was fear that sewers would become silted. Temporary accommodations had to be provided for flood victims, who were bedded in various places. Although much food had to be served under unusual conditions, there was apparently no undue amount of disease. Disinfectant of creosote-base type was furnished to each house with instructions as to use. Cellars were pumped free from water and cleansed, owing to necessity of drying house as well as possible. Additional coal allotments were made to each home. Oil-burning stoves were installed in some homes. For cleansing and speedily drying furniture and coverings, portable hot-air drying machine was lent by military authorities. This consisted of apparatus in which hot air is generated at temperatures from 150° to 170°C.This machine was fairly efficient. At end of article, suggestions are given with respect to future emergencies of this nature.—*P.H.E.A.*

Cross-Connections Causing Illness. H. P. Croft. Public Health News. (N.J. State Health Dept.) **29**:2:38 (Feb. '48) Cross-connection defined by N.J. statutes as ". . . any device which permits or may permit any flow of water into an approved public potable water supply from an unapproved water supply." Records of N.J. Health Dept. indicate 3 instances of epidemics caused by cross-connections. In 1922 cross-connections between public and industrial supply (river) caused typhoid epidemic of 114 cases, 18 deaths. Cross-connections were thought to be "protected" by gate or check valves. Significant that all typhoid cases were concentrated in section of city fed through main connected to industrial supply. In 1923 similar cross-connection caused typhoid epidemic of 41 cases, 4 deaths. In 1942 temporary cross-connection at shipyard resulted in pollution of public supply and 448 cases of illness among shipyard employees. Following 1922 and 1923 epidemics, State Health Dept. adopted sanitary code prohibiting new cross-connections and providing that existing ones could be maintained only by permission of Health Dept. Ten years' experience with code led to conclusion that effective control of cross-connections would be possible only under statutary requirements. Health Dept. sponsored bill in state legislature. Bill was passed 1 mo. after 1942 epidemic. Compliance with law has been obtained in hundreds of cases without resort to legal process.—*P. D. Haney.*

Report of the Division of Sanitary Engineering. H. B. Foote. 22nd Biennial Report, Montana State Board of Health, p. 47 ('43–'44). Name changed from Div. of Water and Sewage to Div. of San. Eng. in 1944. Principal work of division composed of bact. and chem. examn. of water samples, review of plans and field investigations. Little in way of improvements in public water supplies during this biennium but in general mainte-

nance has been satisfactory. Several communities in serious need of public water supplies. Stream pollution studies included problems on municipal sewage and industrial wastes, such as petroleum refinery sugar plant wastes. Division has received many complaints of wet basements and other difficulties due to high ground water. Part of difficulty believed due to irrigation practice. Remedy for high ground water level caused by irrigation is adequate drainage, widespread in scope. Ice jam in Yellowstone R. near Miles City in 1944 caused 14′ flood crest at municipal water plant intake. Shortly after bombing of jam by U.S. Army plane, river subsided. Arsenic poisoning of private shallow (8′–10′) well caused two deaths. When this report prepared no definite conclusions reached other than that death due to arsenic poisoning, that water contained high arsenic content and that it appeared possible for arsenic to be carried through ground by water from allegedly near-by sources. Contamination of ground waters by gasoline was studied. From one or more sources, gasoline has traveled through soil of one community until it has affected number of private wells. Most serious condition resulted in explosion of gasoline fumes and destruction of building by fire. Fumes apparently came through soil and from gasoline-contaminated well located in building. Best protection appears to be securing of water from deeper strata and prevention of gasoline loss. Work on disinfection of water containing tularemia organisms continued and results of experiment indicated that disinfection with chlorine was adequate to remove this contamination. [*See* Jour. A.W.W.A. **35**:902 (July '43).] Extension of water testing laboratories in larger cities necessary due to requirements of U.S. Public Health Service stds.—*P. D. Haney.*

Report of the Division of Sanitary Engineering. H. B. Foote. 23rd Biennial Report, Montana State Board of Health, p. 44 ('45–'46). Principal work of division is bact. and chem. examn. of water, field inspections and review of plans. Bact. water samples from public supplies submitted in iced containers. In Montana 115 cities and towns and 7 state institutions have public water supplies. Of 149 water sources, 92 from ground and 57 from surface. Population served, 303,500—about 55% of state total. Not many major improvements in public water supplies in '45–'46. Distribution system improvements at Billings gave considerable difficulty in disinfection. One city replaced wood distribution system because wood did not withstand soil conditions. Considerable planning for new systems and improvements under way. Stream pollution studies were continued. In '45 state legislature amended stream pollution law in attempt to protect and preserve rights of individual water users as well as rights of public water supply users. High ground water table causes excessive infiltration into sewers in most urban areas.—*P. D. Haney.*

Conditions and Lessons of an Epidemic. Ch. Herter. Monatsbulletin (Swiss) **27**: 89, 126, 181, 208, (in Fr.); 245, 279 (in Ger.) ('47). Typhoid epidemic at Glion, Switzerland in '45 described. 101 cases of typhoid and 16 deaths occurred in pop. of 800. Cause was temporarily pold. water supply, as it was established that only persons affected were those drinking from this supply, which comes from glacial springs. Hotel located above springs and sewer outlet from hotel passes over springs. Cave-in discovered over this sewer line and village president ordered 2 nearest springs closed off from main. Not till 3 weeks later, when epidemic broke out, were state sanitary authorities notified and chlorination installed. This epidemic shows technical incompetence of local political authorities, who had neglected previous warnings. It shows need of permanent chlorination and of state control of supplies. Responsibility for supply should, however, belong to community, with technically trained man in charge who is free of political domination.—*Max Suter.*

Revision of the Regulations for Supplies of Drinking Water. Hayo Bruns. Gas- u. Wasser. (Ger.), **88**:5:141 ('47). Carl Dahlhaus and Hayo Bruns are preparing this revision. Medical authorities in Germany desire more safety measures and engineers more technical details. Not yet decided if it will be fixed standard or in form that can be more easily adapted to scientific progress. Draft shows 5 chapters whose content is only outlined and sixth chapter given in full which contains draft for well construction. Seems to be implied throughout that regulation is justified solely because of need for safe drinking water supply. It is required that the water must be free of sickness-producing organisms, poisons or substances dangerous

to health; but taste, odor, temperature, hardness or iron and manganese content can be disregarded on occasion. Design should be planned for a period of 10–15 yr. ahead, with allowance for future extension. Co-operation among engineers, planners, hygienists, chemists, geologists, hydrologists and biologists is recommended. Sanitary and nonsanitary supplies shall not be cross-connected or separated only by a valve. All construction shall be done in manner to exclude all future contamination. Artificially charged ground water shall pass through 20″ of sand; slow sand filters shall have 40″ sand and rapid sand filters 28″ sand. Chlorination must be done carefully. Personnel of plants shall be trained in cleanliness and have yearly medical examinations. House installations shall be checked by plant for possibilities of contamination of system. Control of rural supplies presents difficulties, but supervision by state must be extended. In checking on water works, main point is in inspection of whole plant; chem. and bact. tests are secondary. Installation of water supply or well drilling requires a permit. No supply can be started until installation has been checked by authorities. Water works installations must be at least 33′ from any source of pollution. Dug and drilled wells must be made watertight to at least 10′ below ground and surroundings of wells must be watertight for 16′ and shall be sloping away from well. Many other details are given, all for purpose of eliminating pollution from wells, pumps, distribution system and storage tanks.—*Max Suter.*

The Hygiene of Water Supplies. A. SCHENZEL. Gas, Wasser, Wärme (Austria) **2**:19 (Feb. '48). Thorough discussion of sanitary and chemical requirements of potable water supplies in light of sad experiences during war, including laboratory technique for testing.—*Willem Rudolfs.*

***Asellus aquaticus* in the Distribution System at Amsterdam.** G. P. H. VAN HEUSDEN. Water (Neth.) **32**:109 (June 10, '48). There are several species of *Asellus* widely distributed in rivers, creeks, ponds, ditches, springs and lakes and living among decaying vegetable matter. *Asellus aquaticus* is common in Holland; males are larger than females, being 20 and 15 mm. respectively. *Asellus* first discharged from tap in Amsterdam in 1923; numbers gradually increasing. *Asellus* feeds primarily on organic matter in water attached to pipe walls. Evidence indicates that it multiplies in distribution system; females carrying eggs and young have been found; there are always white specimens, indicating their presence for a long time in dark; only one species has been found in pumping stations and pipelines. It is assumed that it enters lines through sides of filters. From 1933 to 1940 control was accomplished by frequent sluicing through fire hydrants. This was impossible during war, with resulting increase in number of organisms. Studies with numerous poisons showed that pyrethrin was best. (Pyrefume used, standardized to assay 10 g. of pyrethrin per 100 ml.) Dose used amounted to 2 gamma per l. Only few live organisms were left. —*W. Rudolfs.*

Research and Control. NORMAN J. HOWARD. Can. Engr.—Wtr. & Sew. **81:** 5: 22 (May '43). Origin of nonspecific intestinal disturbances matter of conjecture. At present time, seems to be no ground for assuming that they are water-borne. Possible, but rather improbable, that they are caused by toxins in treated waters previously subjected to excessive poln. Some difference of opinion regarding treatment necessary to destroy *Endameba histolytica*, but every reason to believe that filtration and adequate chlorination will render water supply safe. Recent studies regarding poliomyelitis disturbing, but knowing that virus present at times in untreated water, would expect many more cases if water purif. not effective. Knowledge lacking concerning possibility of attenuated organisms which survive water purif. recovering their virulence, but known that environment modifies morphology and physiological behavior of certain organisms. Coliform test remains recognized yardstick for assessing water qual., but presence of coliform bacteria not definite indication that supply unfit for human consumption. San. survey of source aids greatly in interpreting results of bact. tests. Aftergrowths in distr. system confuse picture, but if water entering distr. system sterile and no danger of secondary poln., no sound reason to question safety of supply if some deterioration in qual. occurs. Chloramine treatment only means of preventing secondary growths and such treatment may become compulsory regardless of san. necessity if present-day stds. of qual. to be met consistently.—*R. E. Thompson.*

BACTERIOLOGY

A Study of a Method of Concentrating Samples of Water for Bacteriological Examination. O. A. Peso. Rev. Admin. Nacional Agua (Arg.) **11**:115:54 (Jan. '47). After reviewing literature on this subject, author describes his experiences in isolating pathogen micro-organisms from water by means of their adsorption on aluminum hydroxide. Gelatinous ppt. freshly prepd. for each expt. by adding slight excess of ammonium hydroxide to 12% soln. of aluminum nitrate, and gel washed several times in distd. water before being sterilized at 100°C. for 15 min. First series of expts. carried out in tap water artificially inoculated with lab. cultures. Floc added to water, thoroughly mixed by stirring, allowed to settle and examd. for adsorbed bacteria by inoculation on recognized solid and liq. media commonly employed for isolation of pathogenic intestinal organisms. In case of *Salmonella typhi*, with 5 to 7 bacteria per l., this organism was recovered by direct plating on Wilson-Blair agar medium and by enrichment in Leifson's selenite and Kauffmann's tetrathionate media. When *Salmonella typhi* mixed with *Esch. coli* in ratio of one of former to over million of latter, *Salmonella typhi* recovered by enrichment of floc in selenite broth, but not by direct plating. Similarly, with cultures of *Salmonella typhi* and *Salmonella typhi-murium*, mixed to give count of about 5 of each type per l., successful isolations made of both on Wilson-Blair medium; and isolations of each type from mixt. of *Salmonella typhi* and *Shigella flexneri* made by enrichment in Leifson's desoxycholate-citrate soln. Second series of expts. on recovery of organisms from alum ppt. from R. Plata water, artificially seeded with pathogenic intestinal bacteria. Mixt. of *Salmonella typhi*, *Salmonella typhimurium* and *Shigella flexneri* type Boyd 2 added to raw river water to give initial count of about 10 of each type per l. Ppt. enriched in Leifson's desoxycholate-citrate soln. and all 3 types recovered by plating out on SS agar. Method of concn. by adsorption on aluminum hydroxide that described by Diénert and Guillerd and seems very satisfactory, particularly in association with types of media now available, which have all been developed in last 25 years. Author claims that recoveries up to 90% of original inoculum have been obtained, and technique should be useful for examn. of pold. rivers and streams for presence of pathogenic intestinal organisms.—*B.H.*

Indications Furnished by Bacteriophage on the Sanitary State of Water Supplies. A. Guelin & J. Le Bris. Ann. Inst. Pasteur (Fr.) **73**:5:508 (May '47). Bacteriophage content of samples of water taken from Seine above and below sewage outfalls estimated, with use of strain of *Esch. coli* susceptible to wide range of phages. Results, which varied according to seasonal and topographical conditions and corresponded roughly with coliform counts, suggested that quantitative estimate of coli-phage content might be used as indication of degree of excretal pollution. It is hoped that it may prove possible to detect in water samples phages active against typhoid bacilli and other pathogens.—*B.H.*

American and English Methods of [Bacteriological] Water Analysis. J. G. Marchal. Bull. Assoc. Diplômés Microbiol. Faculté Pharm. Nancy (Fr.) **29**:38 ('47). Critical discussion of these biol. and biochem. methods.—*C.A.*

Bacteriological Tests on Bathing Places. W. von Gonzenbach & S. Hoffmann. Monatsbulletin (Swiss) **28**:4:84 (Apr. '48). Fundamental difference must be recognized between standards for drinking and bathing water. Very little water is swallowed in bathing and therefore pollution limit can be higher than for drinking water. To require same standard for both waters would be unreasonable. Bacteriological study of 20 open bathing places showed that total count on agar and coli titer do not go parallel; however, coli titer more nearly proportional to number of bathers. Indoor swimming pools should have higher standards, especially as to clearness of water. Coli titer is only useful control test and should not exceed 1.0. Bathing water should not be made disinfecting solution which through too high chlorine content affects eyes of some bathers. Chlorine odors reduce pleasure and number of bathers and thereby act against hygienic benefit which bathing can furnish.—*Max Suter.*

Bacteriological Tests for Drinking Water. Hayo Bruns. Gas- u. Wasser. (Ger.) **89**:2:55 ('48). Bacteriological tests have their value, but they should not be sole determining factor in judging sanitary quality of water supply. If field examination shows pollution to be evident, bacteriological tests may not even be needed. In bacteriological tests, uniform standards in method have to be used to get comparable results. Total count of little sanitary value, although it may show efficiency of filtration process. There are so many types of coli bacteria, so many sources from which they may come and so many tests that it is difficult to determine what is really indication of dangerous fecal pollution. (Although many methods are listed, American methods, using E.M.B., brilliant green, microscopic examination with Gram stain, M.P.N., etc., are not mentioned.) Author is skeptical about too much differentiation of coli group and wants critical interpretation of results to be based on additional findings of periodic tests and thorough field investigation.—*Max Suter.*

Some Problems in the Bacteriology of Rivers. C. L. Hannay. Proc. Soc. Applied Bact. (Br.) ('45). Bact. flora of R. Avon and tributaries studied to find extent flora affected by discharge of sewage and distance this effect persists. Plate counts on nutrient agar at 20°C. and at 37°C., and presumptive counts of coliform bacteria at 37°C. and 44°C. and of fecal streptococci, detd. daily over period of several weeks from various sampling points. Below sewer outfall, bact. numbers increased, and with increasing distance below outfall they decreased rapidly. Effect most marked with coliform bacteria on McConkey broth at 44°C. and with fecal streptococci. Below outfall, fecal streptococci decreased by 97% in less than 3 mi., and below other outfall by 97.4% in 1.9 mi. With methods of counting which included bacteria washed in from river banks, decreases were of lower order. Full effect of marked increase in counts after heavy rainfall evident at some sampling points on actual day of rain, and at other points evident next day. Time taken appeared to depend on position of sampling point relative to storm water discharge and secondary sources of poln. on banks.—*Sew. Wks. J.*

Detection of *Eberthella typhi* in Water. Alfredo Armando Stefanile. Rev. facultad Cienc. Quím. (Argentina) **20**:91 ('45) (Pub. '47). Comparison of results of incubating samples of suspected waters known to contain *Esch. coli* in several media which are expected to suppress growth of other organisms and promote that of *Eberthella typhi.* Medium of Leifson detected more contaminated samples than did that of Kaufmann-Miller; for added assurance, both should be used. Medium of Wilson-Blair was used for isolating. If negative results are obtained after 24 hr. of incubation it should be continued for 48 hr. more. Plating upon the lactose-litmus isolation medium and also the brilliant green agar of Kristensen, Lester and Jurgens requires 24-hr. incubation, and Na desoxycholate agar medium of Wilson Blair requires 48 hr.—*C.A.*

Field Investigation of Paratyphoid Fever With Typing of *Salmonella paratyphi* by Means of Vi Bacteriophage. Monthly Bul. Ministry of Health & Pub. Health Lab. Service. (Br.) **6**:148 (Aug. '47). From '39 to '45, nine cases of paratyphoid fever occurred in Beccles, Suffolk. All ran mild course, occurred in boys and girls between ages of 10 and 13 years, and were discovered each year between 8 July and 20 Sept. In '41, E. C. G. Maddock of Ministry of Health suggested that possible source of infection was Beccles bathing pool on river Waveney. In '44, A. Felix and B. R. Callow identified, by bacteriophage typing, strain which infected 3 boys who had used Beccles bathing pool that summer. This strain did not fall within 5 Vi bacteriophage types then recognized and was provisionally referred to as Vi-type Beccles. Because of known risk, bathing pool has been closed since '45; nevertheless frequent yearly samples of water from about 200 yards above bathing pool to nearly three-quarters of mile below it yielded *Salm. paratyphi B* of Vi-type Beccles. Sewage disposal of bungalows in vicinity of bathing pool investigated and in July '46 it was found that settling tank of one set of buildings could not be located. It was then discovered that there was in fact no settling tank, but that drain led directly into river by submerged entrance. Furthermore, sample from house drain yielded paratyphoid bacilli of Vi-type Beccles and 2 apparently healthy carriers found among persons who used toilets in these buildings. After these findings, toilets of this set of buildings disconnected from drain, night soil being dealt with by other methods. Since this was done, all samples of river water have been consistently negative.—*B.H.*

Quaternary Ammonium Germicides—A Discussion of Methods for Their Evaluation. R. A. Quisno, M. J. Foter & H. L. Rubenkoenig. Soap, **23**:6:141 (June '47). Quaternary ammonium compounds, when tested by phenol coefficient methods, give irregular and unduly flattering results. These authors do not agree with Klarmann and Wright that apparent sterility in such tests due to migration of bacteria to walls of tube, whence sampling with loop will not remove them. In support of this contention, they give results of tests performed in tubes made of 7 different materials which might be expected to affect bacterial migration and apparently did not. Modifications of test which they have studied include shaking medication tubes, introducing glass beads which are removed for cultivation, and cultivation of whole of test mixture in medium containing reagent which neutralizes germicide. This reagent is lecithin rendered soluble by addition of "Tween 80," polyoxyethylene derivative of sorbitan mono-oleate. This constituent can be added to either broth or agar and effect is to reduce coefficient obtained considerably. When agar used, and colony counts can consequently be made, there is considerable range of germicide dilutions in which only few survivors persist. When such agar run into medication tube itself after pipetting out test mixture, results are obtained which suggest that some bacteria survive on surface of test mixture; a physical explanation of this is suggested. General conclusion reached is that phenol coefficient methods are unsuitable for testing germicides so dissimilar to phenol as these compounds, although such methods can be improved by modification. Authors favor use of variety of tests for different types of germicides, based on conditions of their use.—*B.H.*

A New Medium for Study of Quaternary Bactericides. E. H. Armbruster & G. M. Ridenour. Soap, **23**:8:119 (Aug. '47). Serious fallacy in testing disinfecting power of quaternary ammonium compds. is carry-over of disinfectant from medication tube to culture tube, where very minute trace will suffice to prevent growth of viable organisms, especially if they are staphylococci. Authors have devised culture medium which overcomes this difficulty, action of which depends on neutralization of this class of disinfectant by phosphatides. It consists of proprietary thioglycollate broth to which are added Asolectin (purified phosphatide prepn.), "Tween 80" (polyoxyalkylene sorbitan monolaurate, which acts as dispersing agent for foregoing and also has direct neutralizing effect), and small amt. of agar. Four quaternary ammonium disinfectants tested in various ways, by means of 2 different transfer techniques and 2 organisms (*Salmonella typhi* and *Staph. aureus*), and with both this medium and that prescribed for the Food and Drug Admin. regular disinfectant test. Full results given. These are not analyzed and cannot be accurately expressed in any condensed form, but phenol coefficient obtained by ordinary Food and Drug Admin. method will be from 40 to several hundred times greater than that given when this medium used (*e.g.* cetyl pyridinium chloride *v. Salmonella typhi*—all cultures neg. from 1 in 150,000 in Food and Drug Admin. broth; all pos. from 1 in 1,000 in authors' medium). —*B.H.*

NAIDM-USDA Report on Quaternary Ammonium Testing. L. S. Stuart. Soap, **23**:9:135 (Sept. '47). Abbreviations in title stand for National Assn. of Insecticide and Disinfectant Mfrs. and U.S. Dept. of Agriculture, which have collaborated in study of methods of testing quaternary ammonium compds. as disinfectants. Author of report on staff of U.S. Dept. of Agriculture; not clear whether report official pronouncement having authority of that department. Study on which it is based consisted of supplying 3 disinfectants of this type to cooperating mfrs.' labs., where their phenol coefficients detd. by Food and Drug Admin. procedure with various modifications. Pooled results analyzed, and show wide variation: "skips" also common in results of individual tests. ["Time-skip" pos. culture from tube apparently sterile when previously sampled, and "diln.-skip" pos. culture from tube contg. lower concn. of disinfectant than one sampled at same time and yielding no growth.] Not altogether clear from report how or why these results point to desirability of particular modifications of Food and Drug Admin. method, but recommendations given. Test with *Salmonella typhi* performed in conventional way, chief innovation being use of culture medium contg. "Tween 80" and Asolectin which neutralizes disinfectant carried over with inoculum. In test with *Staph. aureus*, culture of organism dried on glass rings which are immersed in disinfectant dilns. and transferred without washing to tubes of same neutralizing medium.—*B.H.*

HYDROLOGY

The Causes and Effects of Sedimentation in Lake Decatur. CARL B. BROWN, J. B. STALL & E. E. DETURK. Bul. No. 37, Ill. State Water Survey ('47), 62 pp. L. Decatur, municipal water supply reservoir of Decatur, Ill., located on Sangamon R. at edge of city. It has drainage area of 906 sq.mi. When built in '22, reservoir had surface area of 2805 acres and storage capac. of 19,738 acre-ft. Sedimentation survey made in '36 showed capac. loss of 1.0% annually. Second survey made in '46 showed loss of 1.2% since '36—20% increase. By '46, surface area of lake had been reduced 201 acres and capac. by 5171 acre-ft. or 26.2%. Consumption of lake water by city and local industries has increased from avg. of 340 mil.gal. per month in '37 to avg. of 428 mil.gal. per month in '44. Future annual increase in avg. monthly consumption estd. to be at rate of 8.7 mil.gal. In 36 yr. ('08–'45) there have been 7 periods of 6 consecutive months in which stream flow at Decatur has been less than present or near-future demands on lake (withdrawal for consumption plus estd. losses from evapn. and seepage). Lowest flow for 6 mo., 3573 acre-ft., which occurred in '14–'15, estd. to have recurrence frequency of once in 35 yr. Increasing consumption and decreasing storage capac. of lake will result in water shortage by '59 if 6-mo. low flow equal to that of '14–'15 should recur. City, however, should guard against probability of even smaller inflow. Considered desirable to provide storage to offset min. flow of 2500 acre-ft. in 6 mo., which is estd. to have recurrence frequency of once in 50 to 100 yr. To provide against this contingency will require addnl. storage by '56. Thus, because of sedimentation, supplementary storage should be provided when present lake 34 yr. old. If no sedimentation had occurred, present lake would have been adequate for 78 yr. Estd. avg. annual inflow to lake from '23 through '35 was 68,000 acre-ft. greater than that from '36 through '45. During earlier period, stream flow exceeded 1000 cfs. for 44.6 days per year on avg.; whereas during later period, it exceeded this rate only 36.7 days per year. This indicates that hydrologic conditions more favorable to erosion and sedimentation during earlier period. Actually sedimentation rate 20% greater during later period. About ¾ of land in drainage area above Lake Decatur has slopes of less than 2%. Remaining ¼, except for $\frac{7}{10}$ of 1%, has slopes ranging from 2 to 15%. Area broad, gently rolling glacial drift plain in heart of Corn Belt. Its black prairie soils intensively used for agriculture. In typical county—Piatt—in '43, approx. 31% of land was in corn; 33½% in soybeans; 11% in small grain; 14½% in hay and plowable pasture; 2% in woodland; and 8% in other uses. About 62% of farms, embracing 72% of land, tenant-operated. Soil conservation practices planned on only 4.2% of land to July 1, '46, and only about ½ of planned practices installed. Turbidity and stream-flow records, anal. of lake sediments, and repeated observations and expts. on land, show that lake sediment derived from all parts of drainage area. Estd. that at least 90% comes from sheet erosion, primarily from corn and soybean fields on slopes of 2 to 15%. Only 10%, or less, comes from gully, stream-channel, and shoreline erosion. Measurements in lake show that shoreline erosion contributes between 1.6 and 6.6% of total sediment. From '36 to '46, 2,650,000 tons of sediment deposited in lake, while estd. 750,000 tons passed over spillway. This constitutes loss of 3,400,000 tons of soil from farms of drainage area during 10 yr. Although this only part of total soil loss, it is equiv. to complete removal of 7″—plow depth—of fertile topsoil from 3400 acres of land. Anal. of plant nutrients in reservoir sediment shows loss from farmland during 24.3 yr. of 2,478,600 lb. of active nitrogen worth \$223,560, and available org. phosphorus worth \$85,050. Much larger losses are involved in some 12,000,000 lb. of reserve nitrogen in org. matter and some 3,500,000 lb. of total phosphorus included in sediment inflow to lake. 20% increase in avg. rate of sedimentation during 10 yr., '36–'46, as compared with preceding 14.2 yr., attributed to progressive increase in intensity of land use for intertilled row crops. In Piatt County, land in row crops increased from approx. 39% in '24 to 64½% in '43. Increase due mainly to soybeans. Present rate of sedimentation estd. to be 30% above avg. rate prior to '36. Possible remedial measures for maintg. water supply and other values associated with L. Decatur include (1) raising present dam, (2) constr. of several small reservoirs on tributary streams, (3) constr. of one or more sizable reservoirs on Sangamon R. above L. Decatur, and (4)

soil conservation measures on drainage area. Dredging not considered economically feasible at present. Complete program of soil conservation on drainage area should include reduction in acreage of land used for intertilled crops, crop rotations involving no more than 2 yr. in 4 of intertilled corn and soybeans, contour planting; and where required, terracing, diversions, grassed waterways, drainage and other practices. Estd. that complete conservation program would reduce sedimentation by 62% from its avg. rate during 10-yr. period, '36–'46, or by 65% from probable present rate. This conservation program would result in higher level of farm income and maint. soil resources of area, as well as protect L. Decatur. Soil Conservation Dists. organized in each of 6 counties in drainage area provide means for accomplishing needed soil conservation work. Estd. that past and future sedimentation will cause damage to Decatur's water storage facilities equiv. to $200 per acre-ft. or $47,200 annually at 10-yr. avg. rate of 236 acre-ft. of deposits. In addn., estd. future loss of $4,375,000 in property values adjacent to lake may result if lake permitted to become 80% filled with sediment. Further damage to community estd. at $40,000 annually will result from loss of recreational facilities if lake allowed to become 80% silted. Probably city would be justified in spending $100,000 annually over next 100 yr., or equiv. present worth now, to effect reduction of sedimentation to 38% of its 10-yr. avg. rate. Furthermore, farmers of area have large stake in maintg. industries and trading outlets in Decatur and can afford to protect their own solids in order to protect water supply of city. This investigation, together with data on few other reservoirs in Illinois, indicates that sedimentation is critical problem in utilization of impounding reservoirs. In '44, 62 cities and towns in Illinois depended on impounding reservoirs subject to sedimentation. Widespread constr. of addnl. municipal reservoirs appears probable.—*Ed.*

Colorado River—Silt Channel Dredging Is Planned. R. W. Davis. Western Constr. News. **22**:10:71 (Oct. '47). Colorado R. rises in Rocky Mts. of Colorado and Wyoming, flows 1400 mi. through high plateaus, deep canyons and broad alluvial desert valleys to Gulf of California. Prior to constr. of Hoover and Parker Dams over 150 mil. tons of silt carried into alluvial valleys inundating area at floodtime. At Needles, Calif., river flows through alluvial valley 25 mi. long and 2 to 5 mi. wide. In past years considerable meandering of river has occurred in valley accompanied by general rise in water level. Rose 11 ft. from '02 to '35 when Hoover Dam constructed. No rise from '35 to '40 but since '40 rise has been greater than before. This presents serious threat to city of Needles and extensive Santa Fe Railway shops and facilities because old levees are being overtopped. Vast areas being transformed into marshy swampland besides threat to transcontinental railroad. Any extra discharge from Hoover Dam would cause extensive damage to Needles and railroad. Bureau of Reclamation assigned C. P. Vetters to investigate and report remedial action in '44. Permanent corrective measures not initated because of lack of congressional authority, but emergency measures started by raising levees and installing pumps to reduce el. of seepage ponded water. Causes and contributing factors to condition described. Characteristic of silt-bearing river is fluctuation of alluvial bed with rise in bed during slow discharge and lowering of bed during floods. Valleys limited in Colorado R. system and separated by mountain chains and gorges with many washes discharging into stream. Floods from washes cause rise upstream because of rocks carried and cleared away by great floods in river. From '35 to '40 river below Hoover Dam silt-free but in '41 river began to scour, picking up deposits years old. Parker Dam at south end of valley closed in '38 causing reduction in river veloc. Caused vast swamps of tules and willows to grow between Needles and Topock with no definite channel for river. Addnl. reduction in veloc. of river caused more sandbars to develop, further hindering flow. Bureau of Reclamation secured amphibious vehicles after war for use in survey of swamp areas. Problem is opening channel of sufficient capac. to handle normal flow of river. Plan channel 250′ wide, 17′ deep, spoil to be used as levee. Will provide temporary relief to Needles and endure for approx. 6 years. New Davis Dam being built above Needles will control silt and may obviate necessity for second channel. Purpose of levee twofold: prevents loss of water, makes possible reclamation of large area. Brief description of proposed dredge.—*A. C. Rener.*

Influence of Weather on Town Water Consumption. C. J. Leadbeater. Commonwealth Engr. (Australia) **34**:363 (Apr. 1, '47).

Effect of seasons, pptn., number of wet days in period, temp., humidity, and hours of sunlight on water consumption discussed in previous article. Geographical location, altitude, winds, local topography and geology, local layout, local circumstances and war conditions relative to water consumption briefly discussed in this article. Formula for estn. of future water consumption—based on gallons per service or per head, effects of temp., humidity and number of wet days in period under anal.—developed, with charts and illustrations.—*P.H.E.A.*

Hydrological Considerations in the Enlargement of Urban and Rural Water Supplies. Ernst Becksmann. Gas- u. Wasser. (Ger.) **89**:4:116 ('48). 1947 year of extreme drought in Europe. With increase of population because of refugees from Russian zone, many German communities had water shortage. To relieve this in presence of shortage of materials forced intensive studies of original water source. Many springs found to collect only part of available water. In rock springs collecting system must be extended to crevice in rock. Care must be taken to avoid bacteriological contamination, which may not exist during drought, but may show up only during wet period. Often water from crevices in rock can be collected by shallow wells in sands of valley deposits. Measurements of yield of wells and of ground water levels necessary over long periods to decide selection of source of water. Wells age, and rehabilitation usually gives only temporary relief. New wells will be needed but should be located with view to future extension. Safety zones around wells should consider extent of protective cover over whole watershed of well. Safety zones may not be needed, even in cities. Circular zones unnatural and may help conscience of designer more than protection of water.—*Max Suter.*

The Role of the Forest as a Water Resource. Walter Carle. Gas- u. Wasser. (Ger.) **88**:4:118 ('47). Investigations by Schubert, Engler, Burger, Valek, Bates and Henry reviewed. Direct evapn. less in forest than in open country, but if water use by plants added, total evapn. about equal. Measurements in mountainous terrain show that forest valleys have higher infiltration, shallower frost penetration, more ground water storage, more uniform runoff and less erosion than nonforest valleys. For flat countries no such data available, but it has been shown that here evapn. more uniform on forest land than in open country. Forest in plains often reaches its roots into ground water zone, increases humidity of air, and so improves climatic conditions. Conservation of forest necessary.—*Max Suter.*

WELLS AND GROUND WATER

Well Pollution by Chromates in Douglas, Mich. Mich. Wtr. Wks. News. **7**:3:16 (July '47). Michigan Dept. of Health informed by phone that water from west wells at Douglas had turned yellow. Wells taken out of service pending report on sample. Dept. lab. reported chromate content of 10.8 ppm. Source of contamn. not difficult to locate. About 3 yr. before, metal plating works established in town and dischgd. chrome and cyanide wastes into a pond, from which it overflowed to east and finally disappeared entirely below ground surface about 1500′ east of plant. West wells of village located approx. 1000′ north of waste pond. It took, therefore, about 3 yr. for chromate to pass horizontally through 1000′ of sand to wells. This movement aided materially by drawdown produced through use of wells. This offers good example of time required for water passage through the drift. Likewise, should poln. of ground structure cease now, it could be prophesied that water from east wells would not be free of chem. poln. for at least 6 yr. and perhaps much longer. Wells of local dairy were similarly contamd. and abandoned and at dept.'s request village council asked to condemn all private wells in village since there was no way of keeping close check on their water qual. Even more serious was possibility for contamg. east wells of village. Should these become contamd. town would be without public supply. 2500′ intervened between wells and point where waste finally disappeared beneath ground surface. Wells located at much lower el. than origin of waste and since they are operated 18 or more hr. each day possibility for contamn. good. Weekly samples being sent to dept. for check purposes. To date samples have all showed absence of chromates. —*Ed.*

Water Well Handbook. KEITH E. ANDERSON. Missouri Water Well Drillers Assn., Rolla, Mo. ('47). This handbook is no textbook but very good compilation of useful data for well drillers. Data on theoretical sections kept very elementary, but detailed information presented on cables, piping and wiring. Between tables are inserted short explanatory remarks. Water requirements, drinking water stds. and water chemistry treated sufficiently for well driller's needs; well hydraulics, however, could stand some expansion. Some data on well permits should be given, as they are so variable from state to state. In all, it can be said that booklet of 200 planographed pages brings together in very convenient form mass of data needed by well driller that is otherwise scattered through many different publications.—*Max Suter.*

Subsurface Weirs and Dams. W. GUEMBEL. Tech. Sanit. et Munic. (Fr.) **42**:70 (Sept.–Oct. '47). Underground weirs and dams are logical applications of modifications and variations of permeability of subsoil, as imitation of nature. After proper study of probable basin and different factors pertaining to hydrology, climate, geology and topography of surface, they are easy to construct. Subterranean weirs, of natural impermeable material, differ fundamentally from surface reservoirs in conception, execution, objective and long-range development. Subterranean reservoirs compare with natural aquifers, available for various purposes. They require 3 essential elements: permeable bed, underground weir or dam and natural or artificial infiltration.—*W. Rudolfs.*

Divining Rod Unreliable for Locating Water Supplies. Abstract from report by L. KEITH WARD. Commonwealth Engr. (Australia) **35**:83 (Oct. 1, '47). Author, former government geologist in South Australia, recommends geological study as best procedure for selection of sites for water wells, and concludes: "The writer has reached the conclusion, after the careful consideration of the claims made by diviners of all kinds and the actual results obtained at sites selected by them, that there is at the present time no mechanical device, nor . . . powers that can be relied upon to indicate without fail the presence or absence of water at a given site."—*P.H.E.A.*

The Optimum Length of a Series of Wells. B. A. VAN NES. Water (Neth.) **32**:22,35 (Feb. 5, 19, '48). Mathematical solution for required length of series of wells for hourly capacity sufficient to maintain minimum annual capital and exploitation costs. Conversely, when length of series of wells is given formula developed will indicate capacity of field.—*Willem Rudolfs.*

The Extraction of Water From Small Ground Water Streams. C. TRUELSEN. Gas- u. Wasser. (Ger.) **89**:5:142 ('48). Extraction of water from small ground water streams offers difficulty only when it is desired to obtain most of water in stream. Some of ground water will always by-pass installation. Well systems across stream will have large losses as wells cannot be drilled close to edges of valley stream. More complete extraction can be obtained with infiltration pipe or gallery built across whole valley along bottom of water-bearing strata. This pipe should be gravel-packed, and extraction can be helped by artificial impervious barrier on downstream side of pipe. Collecting well has to be at lowest point of pipe and inspection wells needed on long lines.—*Max Suter.*

Rational Equipment for a Well of High Yield in Alluvial Deposits. A. VIBERT. Genie Civil (Fr.) **124**:13:250 (July 1, '47). Economic reconstruction in devastated areas requires that wells be designed with dimensions to give greatest yield. To obtain this, well should not only be driven to bedrock, but should have a suction pit of large diam. Casing should go down to drawdown level of highest yield. Diam. of screen should be large in order to produce slow velocities in gravel around screen, although not important to keep all fine material from entering well, as this will clear up soon. Screen should offer little resistance to flow of water. Screen built of hollow brick recommended, laid in rings inclined toward outside at slope little steeper than angle of repose of gravel. Gravel packing should be of avg. grain size of alluvial deposit.—*Max Suter.*

Recharge of Aquifers. R. SOYER. Tech. Sanit. et Munic. (Fr.) **42**:58 (Sept.–Oct. '47). Artificial recharge of aquifers has been practiced since end of 19th century in Europe and was more recently perfected in U.S. In France, where subsurface water abundant, intensive pumping shows decline of available

water. Certain water levels cannot be raised by recharging, but where water table fluctuates with seasons, recharge feasible.—*W. Rudolfs.*

A Recent Example of Artificial Recharge of an Aquifer. A. ACHTEN. Tech. Sanit. et Munic. (Fr.) **42**:76 (Sept.–Oct. '47). Author states that ground waters cannot be systematically exploited to fullest extent with recharging. Town of Ligny, pumping 8000–12,000 cu.m./day, had to abandon supply in spite of fact that originally 400,000 cu.m. of water was available. Recharge raised water table, which had dropped about 30′, to original level.—*W. Rudolfs.*

Ground Water Investigations in the Mobile Area, Alabama. CARL G. B. PETERSON. Alabama Geol. Survey Bul. **58**:1 ('47). Excessive withdrawal of water from shallow wells 25′–90′ deep has caused encroachment of sea water which has flowed up Mobile R. Cl content where salt water has encroached varies from 52 to 8650 ppm. Anals. of ground water and Cl content of well waters given. Water sands 700′–800′ deep have not yet shown salt water encroachment.—*C.A.*

Geology and Ground Water Resources of Parts of Lincoln, Elbert and El Paso Counties, Colorado, With Special Reference to Big Sandy Creek Valley Above Limon. THAD G. MCLAUGHLIN. Colo. Water Conservation Board, Ground Water Service Bul. No. 1, 139 pp. ('46). Anals. of 30 well waters included.—*C.A.*

Ground Water in the Halifax Area, North Carolina. M. J. MUNDORFF. N. Carolina Dept. of Conservation & Development, Div. of Mineral Resources, Bul. 51, 76 pp. ('46). This includes many logs of wells and 49 chem. anals. of waters. Water generally potable, but in few wells rather hard, owing to presence of Ca and Mg bicarbonates.—*C.A.*

Ground Water Resources of Bexar County, Texas. PENN LIVINGSTON. Texas Board Water Engrs. ('47). More than 100 anals. of waters included.—*C.A.*

Relationship of Ground Water to the Discharge of the Leona River in Uvalde and Zavala Counties, Texas. PENN LIVINGSTON. Texas Board Water Engrs. ('47). Thirteen anals. of spring waters included.—*C.A.*

Anderson Uses Horizontal Well Supply. ANON. Am. City. **43**:4:97 (Apr. '48). Increased pollution of White River and greater water demand required Anderson, Ind., to seek new supply. Horizontal collectors from 4 caissons tap aquifer fed from Killbuck Creek. Yield 15.0 mgd. Corporation established by city obtained construction funds from insurance company. City operates system and pays corporation which reimburses insurance company. In 15 yr. city will acquire system from corporation for $1.00. Cost of system approximately $500,000. New supply softer, requires no treatment, has more constant temperature and is delivered at no increase in customers' rates.—*F. J. Maier.*

An Eight-Mile Search for Water. L. E. STARK. Am. City **43**:4:104 (Apr. '47). Wells drilled near Marshall, Mo., during last 50 yr. have gradually deteriorated in quality and availability of water. During same period demand increased. Zeolite softener installed in '32 abandoned because of insufficient water for backwashing. New study revealed field 8 mi. from city providing 4.0 mgd. Water has hardness of 225 ppm., iron 3.0 ppm., CO_2 8.0 ppm., and pH 7.6. Softening plant, located at well field to reduce corrosion of transmission main, consists of: indoor aerator with blower, Accelator (1.5 gpm. per sq.ft.), carbonizer, coagulation basin (1.0 hr.), second carbonizer, 2 filters (1.0 mgd. each), pumping and chlorination facilities. Pneumatic and mechanical chemical handling provided. Total cost $620,000.—*F. J. Maier.*

Development of Ground Water Supplies in the Amazon Valley. JOHN L. HUMMEL. Jour. Inter-Amer. Assn. San. Eng., Washington, D.C. **1**:49 (July '47). Article describes problem involved in obtaining ground water from strata consisting of water-bearing sand. This problem overcome by construction of special well employing porous intake panels to exclude sand and prevent surface collapse around well. Method of construction, yield and depth of well discussed. Detailed construction drawing given.—*P.H.E.A.*

Saving Australia's Artesian Waters. ANON. Wtr. & Wtr. Eng. (Br.) **50**:127 (Mar. '47).

Disturbed by evidence that waters of Great Artesian Basin may disappear, commonwealth is working on scientific conservation, and planning an end to waste. Area of intake beds for basin is estd. at 60,010 sq.mi., and area of basin at 600,000 sq.mi. From 1874, when basin was found, to '40 number of bores was 8244; daily flow was 352 mil.gal. (Imp.); min. depth 10′ and max. 6000′; temp. ranged from 10°F. [*sic*] to 212°. While some diminution of supply appears inevitable, rate of decline in flow of bores may be diminished by better methods of controlling it. Conservation calls for more rigid control over operation of bores in existence and complete control over right to put down more. Uncased bores will require casing. Volume may have to be varied according to season. Considerable capital expenditure may ultimately be necessary.—*H. E. Babbitt.*

Construction of a Ground Water Supply for Berne, Switzerland. Monatsbulletin (Swiss) **27**:12:269. (Dec. '47). This project still under constr. and some of difficulties encountered described. Four shafts of 13′ od. and 10′ id. were sunk pneumatically to depths of from 52′ to 56′. From these, horizontal wells were drilled radially by pushing casing with perforated headpiece horizontally. Screen then put inside casing and casing without headpiece pulled back, but leaving 6′ to 12′ of casing outside shaft for sanitary protection. (These wells therefore similar to Ranney wells, although in Ranney wells screen directly pushed to make horizontal well.) 13-mi. pipeline to city built of about 36″-diam. spun reinforced-concrete pipes 8′ long, with bell-and-spigot joints. These pipes stored under water directly after mfg. until needed for use. Each pipe set on 1 or 2 concrete saddles.—*Max Suter.*